

**A HYDROLOGIC ANALYSIS
OF THE
OZARK AQUIFER
IN THE
ROLLA AREA, MISSOURI**

by
James E. Vandike

Cover Photo: Test-pumping the City of Rolla Well No. 1 at Seventh and Walnut streets about 1930. J.B. Bronson, standing second from left, headed the operation of Rolla's power and water systems from 1924 to 1970. Identity of the other people in the photo are not known. Uncredited photograph, courtesy of Rolla Municipal Utilities.

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ABSTRACT

The Ozark aquifer in the Rolla area is a 1,000 ft- to 1,200 ft-thick sequence of nearly horizontal Ordovician and Cambrian cherty dolomites and minor sandstones. Specific capacity of fully penetrating wells ranges from less than 1 gpm/ft to about 27 gpm/ft. Transmissivity varies from about 4,000 gpd/ft to more than 25,000 gpd/ft; where unconfined specific yield is about 0.1.

Groundwater withdrawals from the aquifer has caused an average water-level decline in City wells of 3 ft/year. Since 1900, approximately 32.6 billion gallons of water has been produced in Rolla and the rural Rolla area; about 72 percent of this was produced by the City. A prominent northeast-trending cone of depression about 4 mi long and 1.5 mi to 2 mi wide has developed in the

Ozark aquifer in Rolla. The axis of this drawdown cone roughly parallels I-44 in the western and northern parts of the City. Water-level declines in excess of 200 ft have occurred near City wells #9 and #10, but average water-level decline is between 75 ft and 100 ft in Rolla, and less beyond the corporate boundary of Rolla.

Future lowering of water-table elevation is likely to occur in and near Rolla. Magnitude of the water-level change will depend on population and per capita water-use changes. Further drawdown in the City can be minimized by selectively using the highest-yielding wells in areas of the least water-level decline, and decreasing use at low-yielding wells in areas of the greatest water-level decline.

INTRODUCTION

For nearly 90 years, residents of Rolla have received water from a public water supply system. Prior to construction of the first deep well by the City in 1907, residents supplied water to themselves using cisterns and shallow wells. These individual private systems probably supplied an adequate volume of water much of the time, but were not adequate to meet needs during droughts or even through dry summer months. A growing town needed a more dependable supply of water than cisterns and shallow wells offered, so in 1906 the City contracted for the drilling of the first well.

From 1906 to 1945, the water supply system was owned at different times by the City, and by private individuals and companies. Since 1945, the system has been owned by the City, and operated by a board of public works as Rolla Municipal Utilities.

Rolla has changed in many ways since the first City well was drilled. Population at that time was less than 2,000; yearly water use by the residents was probably less than 20 million gallons. In 1990, the 15 wells supplying the City produced a total of about 730 million gallons of water for 14,100 residents, the University of Missouri-Rolla campus, numerous businesses, and several industries.

As the first century of its operation draws to an end, Rolla's water supply system has produced an estimated 23 billion gallons of water from the Ozark aquifer; 19.2

billion gallons have been produced since 1957. The City of Rolla, as well as nearly every person in the Rolla area, depends entirely on groundwater produced from the Ozark aquifer for water supply. Use of this aquifer is shared with several other nearby major water users including the City of St. James, the Phelps County Public Water Supply District #2, and several private high-yield well owners. Additionally, there are several thousand private domestic wells within a few miles of Rolla that produce water from this same aquifer.

In August, 1991, Rolla Municipal Utilities (RMU), and the Missouri Department of Natural Resources, Division of Geology and Land Survey (DGLS) began a cooperative study to determine the effects of groundwater withdrawal on the Ozark aquifer in the Rolla area. To date, the Rolla area, including the City of Rolla, has not experienced significant water-supply problems. However, an analysis of the aquifer, the City's groundwater supply system, and area water-use information is necessary to determine if groundwater withdrawal is causing excessive water-level decline in the Ozark aquifer, and to help Rolla Municipal Utilities and other area water producers maintain the integrity and longevity of their supplies.

Much of the detail presented in this report is possible due to extensive water well and production records maintained by Rolla Municipal Utilities. Since 1957, RMU

has regularly measured pumping and non-pumping water levels, pumping rates, length of pumping periods, amount of water pumped, and other pertinent information for each well, and entered the data into ledgers. As part of this study, DGLS developed a computerized data-storage system into which RMU entered 34 years of records. Monthly averages and totals were entered for data from 1957 to 1983; daily records were entered from 1983 through 1990. Without these data, much of this study would not have been possible.

From 1924 to 1970, J.B. Bronson headed operation of Rolla's power and water systems, first for American Utilities who then owned the systems and after 1945 for City of Rolla. After he retired, Mr. Bronson prepared a manuscript for RMU entitled *The History of the Electric and Water Systems in Rolla, Missouri*. Not previously published, the report presents an interesting account of the early days of public water and electrical power in Rolla. Because of its historic value and general interest, J.B. Bronson's manuscript, with minor editorial changes, is included as a separate section in this report.

HYDROGEOLOGIC CHARACTERISTICS OF THE OZARK AQUIFER IN THE ROLLA AREA

The Ozark aquifer is a series of nearly horizontal cherty dolomite and sandstone formations more than a thousand feet thick. Each of the formations has differing hydrologic characteristics; some yield little water while others have high yields. Groundwater is stored in, and moves through, openings in the bedrock. Unweathered and unfractured dolomite is nearly impermeable and allows little water movement, but in the Ozarks the dolomite contains numerous vertical fractures called joints that have been enlarged by solution activity from slightly acidic groundwater. Additionally, chemical action of groundwater in the horizontal zones between successive rock beds, called bedding planes, has created additional openings. Groundwater movement in the Ozark aquifer is primarily through these solution-enlarged openings in the rock. The term "groundwater reservoir" is often used, and to many people brings to mind a large opening in the bedrock housing an underground lake. This is not usually the case. Groundwater, for the most part, is stored in relatively small openings dissolved in the dolomitic bedrock. Exceptions to this do occur. The large springs for which the Ozarks is so famous are essentially extensive water-filled caves. Most wells do not penetrate such cave systems.

Aquifers are classified as unconfined or confined. In an unconfined aquifer the water table forms the upper boundary of the aquifer. The water table is the two-dimensional surface between unsaturated rock above the water table and the saturated rock below it. In a well drilled into an unconfined aquifer, the water table is the water surface in the well. A confined aquifer is bounded above and below by low-permeability confining layers called aquitards which allow little water to move through them. Water level in a tightly cased well drilled into a confined aquifer will usually be some distance above the top of the aquifer due to the head pressure on the water in the aquifer. An aquifer having such characteristics is termed an artesian aquifer, and the well an artesian well.

If the water level in the well rises above land surface, it is termed a flowing artesian well. The height to which water will rise in wells penetrating an artesian aquifer defines the potentiometric surface of the aquifer.

There are several properties of aquifers including transmissivity, storativity, and vertical hydraulic conductivity that describe their water-yielding characteristics. Numerical values for these aquifer coefficients can be determined from carefully controlled pumping tests on wells, and can be used to quantitatively predict the response of an aquifer to the addition or removal of water.

Transmissivity and hydraulic conductivity are measures of how easily water can move through an aquifer. Transmissivity is defined as the amount of water, in gallons per day, which will move through a 1-foot wide vertical strip of the saturated thickness of the aquifer under a hydraulic gradient of 1 foot per foot. It is equal to the hydraulic conductivity of the aquifer times its saturated thickness. In an unconfined aquifer, the hydraulic gradient is the slope of the water table; the hydraulic gradient in a confined aquifer is the slope of the potentiometric surface. The transmissivity of an aquifer controls the amount of water which the aquifer will yield. Aquifers with high transmissivities can yield greater volumes of water than aquifers with low transmissivities.

The storativity of an aquifer is a measure of the amount of water a given volume of aquifer can store. In an artesian aquifer it is defined as the amount of water which can be taken into or released from storage per unit surface area of the aquifer per unit change in hydraulic head normal to the potentiometric surface. For example, if a 1 ft² area of an aquifer yields 0.01 ft³ of water with a 1 ft decline in water level, the aquifer has a storativity of 0.01. Under artesian conditions, water

released from storage in an aquifer is from the expansion of water and aquifer compaction caused by changes in fluid pressure; openings in the aquifer are not dewatered. In unconfined aquifers, water released from storage is from dewatering of openings in the aquifer. Storativity of an unconfined aquifer is generally called specific yield, and it is related to the effective porosity of the aquifer. The effective porosity is the ratio of the volume of interconnected voids per unit volume of the rock. Storativity values are dimensionless, and for confined aquifers typically range from 0.005 to 0.00005 while those for unconfined aquifers are much larger, usually between 0.01 and 0.30 (Freeze and Cherry, 1979). With two aquifers with equal transmissivities but differing storativities, the aquifer with the higher storativity will have less head change or lowering of water level in the aquifer when a given volume of water is removed.

Vertical hydraulic conductivity is a measure of the amount of water which will move vertically through an aquitard or confining bed. It is defined as the volume of water, in gallons per day, which will move vertically through a one square foot horizontal area of the aquitard under a hydraulic gradient of 1 foot per foot. Aquitards with low vertical hydraulic conductivity will allow little water to pass through while those with high vertical hydraulic conductivity may have considerable leakage through them.

Some aquifers such as thick, uniform, sandstones have hydrologic characteristics that do not change greatly with respect to position or direction in the aquifer. In such aquifers, well yield and the response of the aquifer to pumping is very predictable. However, carbonate-rock aquifers such as the Ozark aquifer typically are not uniform in composition nor in hydrologic characteristics. For practical purposes, the Ozark aquifer is a series of stacked aquifers that are hydraulically connected. Each formation has its own hydrologic characteristics that vary vertically through the formation, and laterally within the formation. Some zones within the Ozark aquifer, such as the Upper Gasconade Dolomite, yield little water and are essentially leaky confining beds. The major water-yielding zones in the aquifer occupy a relatively small portion of the aquifer.

The Ozark aquifer is an extremely complex hydrologic system that receives, stores, and transmits large volumes of water. Recharge to the aquifer is from precipitation that may enter the aquifer a variety of ways. Spring systems, which are supplied from the aquifer, receive considerable recharge through karst features such as sinkholes and losing streams. This water travels through relatively large bedrock openings, following the conduit systems which channel water to the springs. This type of recharge remains underground a relatively short time before it emerges at a spring. Much of the recharge to the

aquifer is diffuse, and occurs as water from precipitation moves downward through the soil materials, residuum, and weathered bedrock, through fractures and bedding-plane bedrock openings, until it reaches the saturated portion of the aquifer.

Imes and Emmett (in press) calculate that about 25 percent of the average annual precipitation enters the subsurface and provides recharge to the Ozark aquifer. Much of this recharge, however, returns to the surface through spring systems and other means before it enters the regional flow system. Only about 6 percent of the average precipitation provides recharge to the Ozark aquifer regional flow system.

Annual precipitation in the Rolla area varies considerably, but averages about 38 inches. Between 1957 and 1991, annual precipitation varied from a high of 69.4 inches in 1985 to a low of 28.3 inches in 1971. Figure 1 shows average monthly precipitation at University of Missouri-Rolla for 1957 through 1990, deviation from monthly precipitation, and deviation from average yearly precipitation.

Based on recharge estimates by Imes and Emmett (in press), recharge to the Ozark aquifer may be as high as 9.5 in./yr, of which about 2.3 in./yr is enters the regional flow system.

Water in the Ozark aquifer is not static; the aquifer is a dynamic flow system where water is continuously in motion, moving from areas of recharge where water is introduced into the aquifer to areas of discharge where it surfaces. Prior to significant groundwater withdrawals, the aquifer essentially was under steady-state conditions where average discharge from the aquifer equalled average recharge to the aquifer. This equilibrium changed locally with development of wells.

When a well pump is started, water level in the aquifer surrounding the well is lowered. Water level in the well is below water level in the surrounding aquifer, so water moves from the aquifer into the well to replace the water being withdrawn. The amount that water level is lowered depends on several factors, including the pumping rate, how long the well is pumped, and transmissivity and storativity of the aquifer. The longer the well is pumped and the higher the pumping rate, the greater the water-level decline, or drawdown, in the well. Water moves radially toward the well from the surrounding aquifer. As the water nears the well it must flow through successively smaller cross-sectional areas. To do so, velocity of the water must increase. The increase in velocity comes from steepening of the hydraulic gradient as water nears the well. Around the pumped well, the water-table or potentiometric surface forms a cone-shaped depression, called the cone of depression or drawdown cone, that

extends radially from the pumped well into the surrounding aquifer. The distance from the well to the edge of the cone of depression is called the radius of influence. If the well is pumped indefinitely, water-level in the well will continue to lower and the cone of depression will continue to expand until it reaches a point where aquifer recharge within the radius of influence equals the amount of water produced from the well, or until the natural discharge moving through the aquifer intercepted by the drawdown cone equals the amount of pumping. At this point, the aquifer reaches steady state conditions.

Aquifer coefficients such as transmissivity, storativity, and vertical hydraulic conductivity are normally obtained by performing carefully controlled pumping tests. Ideally, a pumping test should be conducted by pumping a well at a constant rate for an extended length of time, and measuring the response of the aquifer to pumping by measuring water-level changes at one or more observation wells a distance from the pumped well. Unfortunately, because of their expense, observation wells are seldom drilled for pumping tests in the Ozark aquifer, so the only drawdown data that is collected is from the pumped well. Transmissivity values can be calculated from these data, but are less accurate than those calculated from separate observation wells. Storativity calculations require drawdown measurements taken a known radial distance from the pumped well, so without an observation well storativity cannot be calculated. Most pumping tests in the Ozark aquifer are simply performance tests conducted on newly drilled wells. They provide valuable information about the performance of the well, but provide little information about the response of the aquifer to the pumping. The pumped wells are often tested for only a few hours, and seldom more than 24 hours, but the information is still valuable, especially when sizing the pump for a new well. Typically, new wells are test-pumped long enough for drawdown in the well to stabilize. Drawdown is greatest when the pump is first started, and decreases exponentially with time. When the pump is stopped, water-level in the well rises. Like drawdown, recovery is fastest immediately after the pump is stopped and decreases with time.

Drawdown data collected from a pumped well are not always adequate to accurately calculate transmissivity, but the specific capacity of the well can be determined. Specific capacity is simply pumping rate (gallons per minute) divided by the number of feet of drawdown in the well. For example, a well producing 300 gallons per minute with 15 feet of drawdown has a specific capacity of 20 gpm/ft. Transmissivities can be estimated from specific conductivity data. For a pumping period of 24 hours, transmissivity (gpd/ft) is approximately 1000 times the specific capacity for unconfined aquifers, and 2000 times specific capacity for confined aquifers (Walton, 1962, p. 12-13).

Specific capacities for wells fully penetrating the Ozark aquifer in the Rolla area show considerable variation, ranging from as little as 1 gpm/ft to more than 27 gpm/ft (figure 2). Wide variations in specific capacities such as these are common in carbonate aquifers. Since water-productivity in carbonate units depends mostly on secondary hydraulic conductivity from solution-enlarged openings, wells intercepting few openings will often yield poorly, while wells intercepting numerous solution-enlarged openings will yield several times as much water with the same amount of drawdown. In the Rolla area, data indicate the highest yielding areas of the Ozark aquifer are east, northeast, and north of the center of town. However, even in these areas, low yields are still possible. Specific capacity is not necessarily a constant, since it is a function of both the well and the aquifer. Specific capacity of several of the older wells in Rolla has decreased while it has increased slightly for other wells. For example, when drilled in 1934, well #2 had a specific capacity of 14.6 gpm/ft. In 1988, specific capacity was 4.0 gpm/ft. The well was capable of producing about 440 gpm when first drilled, but in 1988, the last year of extensive production from the well, it averaged 187 gpm. Decrease in specific capacity of the wells may be due to calcite or other mineral deposition in bedrock openings in or near the well, which decreases the amount of water which can enter the well bore. It does not necessarily indicate a decrease in productivity of the aquifer in the area of the well. Acidizing the well will often result in a significant increase in specific capacity and yield.

Specific capacities shown in figure 2 indicate transmissivity of the Ozark aquifer is higher in the areas adjacent to Rolla to the east, northeast, and north. Little data are available for areas adjacent to Rolla in other directions. However, not every well drilled in the more favorable areas will have good water-yielding characteristics. The variability of the carbonate aquifer is such that there is always a chance, even in favorable areas, of encountering low-permeability zones and having a well with poor yield.

Transmissivity values have not been determined for all of the fully penetrating Ozark aquifer wells in the area. Pumping tests performed on several area wells show transmissivities ranging from less than 4,000 gpd/ft to more than 12,000 gpd/ft. Based on estimates from specific capacity data, transmissivities may be as high as 25,000 gpd/ft in some areas. Imes and Emmett (in press) estimate lateral hydraulic conductivity in the Ozark aquifer to range from about 0.0008 ft/sec (517 gpd/ft²) to 0.00001 ft/sec (6.5 gpd/ft²). Using a saturated thickness of 700 ft, transmissivity would range from about 362,000 gpd/ft to 4,550 gpd/ft. Transmissivity of the Ozark aquifer in the Rolla area probably varies from about 4,000 gpd/ft to about 25,000 gpd/ft.

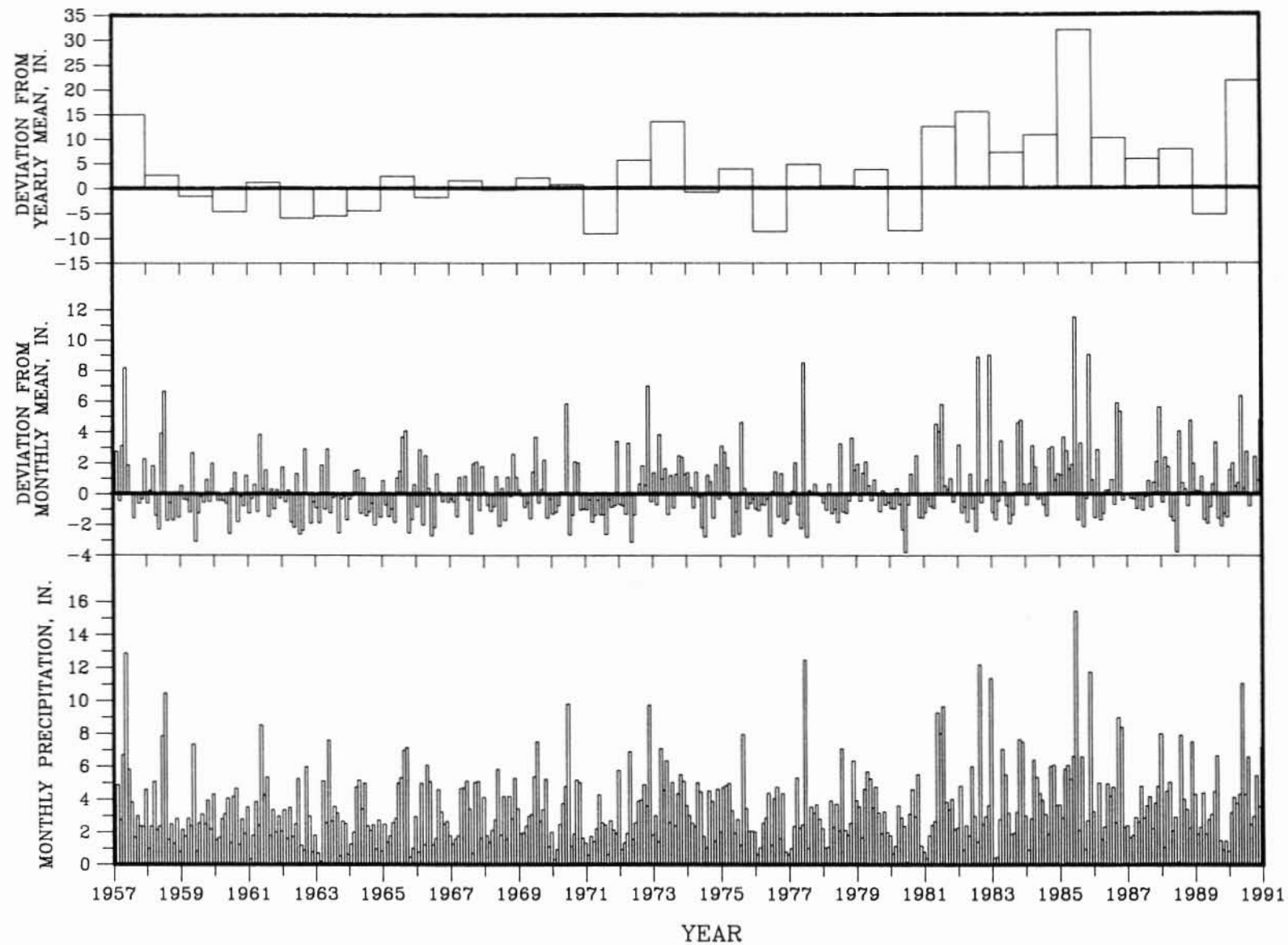


Figure 1: Monthly precipitation, deviation from monthly mean, and deviation from yearly mean. (Data source: Climatological Data for Missouri, National Climatic Data Center.)

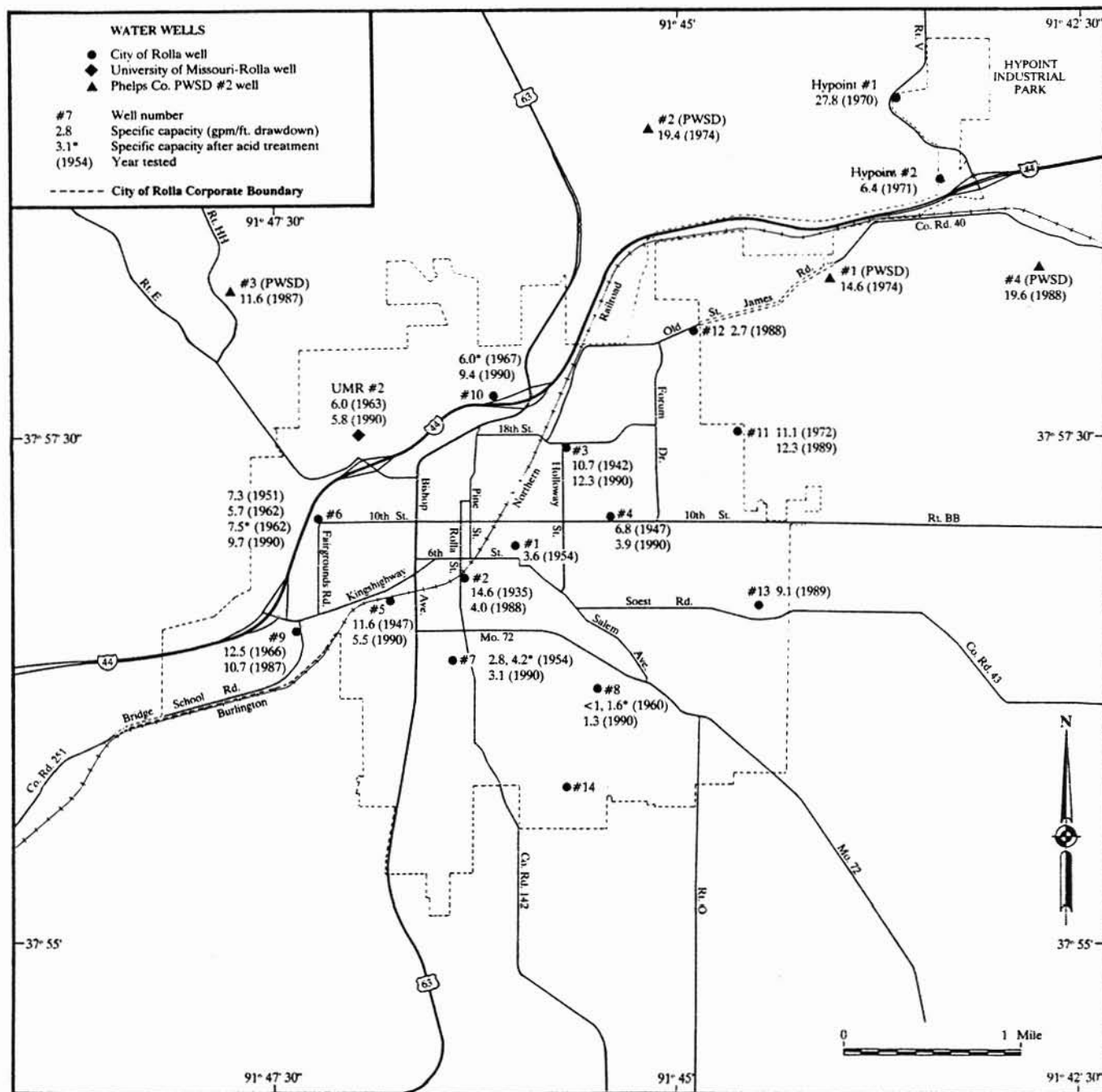


Figure 2: Specific capacities for Rolla, University of Missouri-Rolla, and Phelps County PSD #2 wells.

Depending on location, the Ozark aquifer may be under confined (artesian) or unconfined (water table) conditions. In the Springfield Plateau and other places where it is overlain by confining beds, it is a confined aquifer and generally under artesian conditions. There is generally no effective upper confining unit in the Rolla area, so here the aquifer is not confined, and is under water table conditions (Imes, 1990). Locally, the aquifer

may be semi-confined and under leaky artesian conditions where low-permeability units such as the Jefferson City Dolomite or Upper Gasconade Dolomite act as leaky confining units. The storativity of the Ozark aquifer in the Rolla area has not been determined under field conditions. Where unconfined, Imes and Emmett (in press) estimate the storativity, or specific yield, to be 0.1. Where confined, it is estimated to be 0.004.

GROUNDWATER SUPPLY IN THE ROLLA AREA

INTRODUCTION

The Ozark aquifer in the Rolla area includes the rock sequence between the base of the Pennsylvanian System, and the top of the Upper Cambrian Derby-Doerun Dolomite. This aquifer is a sequence of mostly dolomite formations with lesser units of sandstone. Dolomite is a calcium-magnesium carbonate. It and limestone, which is calcium carbonate, comprise most of the sedimentary rock in the Ozarks. Chert, commonly called flint, is a very resistant silicate mineral that is interspersed in varying amounts in the dolomite formations. Geologic formations included in this sequence, in descending order, are the Cotter Dolomite, Jefferson City Dolomite, Roubidoux Formation, Gasconade Dolomite, Eminence Dolomite, and Potosi Dolomite. Depending on surface elevation, these units have a combined thickness of 1,000 to 1,200 feet (ft) in the Rolla area.

Although these formations are all part of the Ozark aquifer, they have individual characteristics that to a great extent control their water-yielding characteristics. The Jefferson City and Cotter dolomites, which form the uppermost part of the Ozark aquifer in the Rolla area, are exposed at land surface in Rolla and much of the surrounding area. Due to its high stratigraphic position, the Cotter Dolomite is present only at higher elevations around Rolla. The Jefferson City Dolomite has a much wider areal extent. Combined, these units have a maximum thickness of about 275 ft in the area, but at lower elevations along major streams may be absent due to erosion. Since the Cotter is thin in the Rolla area it is not an important aquifer zone. The Jefferson City Dolomite yields modest amounts of water, typically less than 10 gallons per minute (gpm); many older wells in the upland areas around Rolla bottomed in this unit.

The Roubidoux Formation in the Rolla area is probably the most widely used zone in the Ozark aquifer for private water supply. The Roubidoux underlies the Jefferson City Dolomite, and consists of interbedded cherty dolomite, sandstone, and sandy dolomite. Its thickness varies from about 115 ft to 145 ft, averaging

about 130 ft. Yields of wells producing from the Roubidoux in the Rolla area are generally 10 gpm to 40 gpm. However, because of its high permeability, where the Roubidoux is exposed to the surface it can easily become contaminated. Thus, many shallow private wells open to the Roubidoux produce water containing bacteria and excessive nitrate. Water quality problems are less likely to occur where the Roubidoux is overlain by 50 ft to 100 ft of Jefferson City Dolomite. Nearly all of the public water supply wells in the area, including those serving Rolla and Phelps County PWS #2, are cased through the Roubidoux Formation.

The Roubidoux Formation is underlain by the Gasconade Dolomite, which is subdivided into three units. The Upper Gasconade, 45 to 85 ft thick and averaging 65 ft thick, is a dolomite with low chert content. This unit has relatively low permeability, and is typically the zone into which Rolla city wells are cased. The Lower Gasconade Dolomite is from about 175 to 220 ft thick, and consists of cherty dolomite. The basal unit in the Gasconade is the Gunter Sandstone member whose thickness averages about 20 ft in the area. In some parts of the Ozarks, the Gunter is entirely sandstone. However, in the Rolla area, sand content in the Gunter is typically less than about 20 percent. Total thickness of the Gasconade Dolomite at Rolla averages about 300 ft, and the unit has a relatively high yield. Wells fully penetrating the Gasconade typically yield 75 gpm to 125 gpm. The Gasconade Dolomite is the basal Ordovician formation in the Ozarks.

The Eminence Dolomite, which consists of about 275 ft of dolomite with minor chert, is the uppermost Cambrian formation in the Ozarks. It is underlain by about 240 ft of Potosi Dolomite, which consists of dolomite, chert, and drusy quartz. The Potosi is typically the most productive aquifer zone in the area, but, because wells seldom produce only from the Potosi, its yield is difficult to estimate. Wells producing from the Gasconade, Eminence, and Potosi dolomites in the Rolla area typically yield 350 gpm to as much as 1,000 gpm.

All of the City wells penetrate the Potosi Dolomite, and are open through the Lower Gasconade, Eminence, and Potosi dolomites. Prior to construction of City of Rolla, well #3, it was commonly thought that large volumes of water could not be obtained from dolomite units. Thus, City wells #1 and #2 were drilled through the Ozark aquifer into the Lamotte Sandstone, the basal unit of the deeper St. Francois aquifer. The St. Francois aquifer typically yields much less water than the Ozark aquifer, and is the deepest aquifer in the Ozarks. Precambrian rocks underlying the St. Francois aquifer are not permeable, and yield little or no water. The top of the Lamotte is about 550 ft below the base of the Potosi Dolomite; geologic formations between them are, in descending order, the Derby-Doerun Dolomite, Davis Formation, and Bonneterre Formation. It was later found that the Lamotte did not yield enough water to warrant the additional cost of drilling, and installation of liner through shales in the Davis Formation. Beginning with well #3, City wells were drilled through the Potosi Dolomite into the upper part of the Derby-Doerun Dolomite, and cased through the upper Gasconade Dolomite. The only exception is well #8. Because of the low yield of the Potosi at this well, it was drilled through the Bonneterre Formation. Unfortunately, yield did not increase with deeper drilling.

WATER WELL CONSTRUCTION

Simply defined, a water well is a vertical hole drilled into the earth materials to a point below the water table, that is constructed for the purposes of producing groundwater. Over the years, drilling techniques have changed. For many years, the cable-tool or percussion method was used for most well drilling. This method uses a several-foot long cylindrical steel bit suspended at the end of a cable to drill the hole. The lower cutting end of the bit is either hardened steel that is sharpened, or the end of the bit may contain tungsten carbide buttons. The bit is raised and lowered, allowing it to sharply strike the bottom of the hole, breaking a small amount of rock with each impact. Each few feet of drilling, the bit is removed from the hole and the rock cuttings bailed from the hole. All City of Rolla wells prior to well #11 were drilled by cable tool. Subsequent wells were constructed using air-rotary drills.

Most wells today are drilled using air-rotary techniques. Here, a bit is attached to the lower end of hollow drill pipe. The pipe and bit slowly rotate to grind rock at the base of the drill hole. High-pressure air is pumped down the inside of the drill pipe and through the bit. The air cools the bit and blows the rock cuttings to the surface. There are many types of bits that may be used,

but much of the drilling today uses hammer bits that operate from the high pressure air much like a large jackhammer to quickly drill the hole.

Regardless of the drilling technique employed, all rock wells such as those drilled in the Rolla area have similar construction characteristics. However, there are numerous differences between construction techniques used for private domestic wells designed to supply an individual household or farm, and those used for public water supply wells. Private wells in the Rolla area are usually 6-in. diameter, and 250 ft to 400 ft deep; they are typically constructed to supply 15 to 20 gpm. Private well construction standards today require a minimum of 80 ft of casing in most places in the Ozarks, but older wells typically contain much less casing. Casing is pipe placed in the well to prevent soil and residual materials from collapsing into the well bore, and to protect the well from contamination. In a private well, the 6-in. diameter casing is set into an 8-in. diameter hole, leaving about 1 in. of annular space between the outside of the casing and the drill hole that is typically filled with rock cuttings from the well, or a cement slurry poured around the outside of the casing from the top. Since the casing may not be adequately sealed using these techniques, many private wells become contaminated with bacteria.

Public water-supply wells, such as those constructed for cities, larger subdivisions, and public water supply districts, are constructed to more stringent specifications. They are cased much deeper than most private domestic wells. The casing is heavier weight, and is placed into a drill hole 4 in. larger in diameter than the casing. The casing is sealed by forcing neat cement grout (a mixture of cement and water) down the inside of the casing, and up to the surface on the outside of the casing. This completely fills the space between the drill hole and the casing with cement. Wells sealed in this manner rarely become contaminated. Of the few that do, most receive the contaminants from a nearby abandoned well that is contaminated. These wells are also drilled much deeper than private domestic wells. The additional depth is necessary to provide the higher yield that is required. They are also typically larger in diameter than private wells for two reasons. In general, larger diameter wells will yield more water than smaller wells. Also, the larger diameter is necessary to accommodate the high-capacity pumps that are necessary to produce large quantities of water.

Another major difference between private domestic wells and public water supply wells is, of course, their cost. The cost of a high-yield public water-supply well is likely to be 20 to 50 times the cost of a private domestic well.

CITY OF ROLLA WELLS

Since Rolla began supplying water to the public, the City has used a total of 18 wells, 15 of which are still in production. The two earliest wells drilled for the City, the first in 1906-1907 and the second in 1929-1930, have been abandoned and plugged. The third well, now designated well #2, was drilled in 1934 and 1935. It and all successive City wells are still in production.

Currently, these wells are capable of producing approximately 8,500 gpm, which is about 5 times the current average daily water use. The following section summarizes the physical and hydrologic characteristics of each well, and the production history of the City wells currently in use. The wells are discussed in chronological order of their addition into the water-supply system. Locations of the city wells and other selected high-yield wells in the Rolla area are shown on figure 3. Tables 1 through 30 show monthly and yearly production amounts and production percentages for City wells #2 through #13, UMR well #2, and Hypoint wells #1 and #2.

Old City Well and City of Rolla, Well #1

Rolla's first public water supply well was completed in 1907. It was drilled to a total depth of 930 ft, and contained several strings of casing including 39 ft of 10-in. diameter, 185 ft of 6-in. diameter, 195 ft of 5-in. diameter, and 465 ft of 4.5-in. diameter. The well produced about 200 gpm without benefit of a pump. Compressed air was used to force water to the surface. It was Rolla's sole well for more than 20 years, but tended to produce sediment and declined in yield in later years. It was apparently plugged and abandoned sometime during the late 1930s or early 1940s, the exact date is unknown. Some City records indicate the well was plugged in 1937, but letters on file at DGLS indicate the well was plugged sometime after 1941.

Rolla's next well, designated well #1, was completed in 1931 at a total depth of 1,710 ft, into the Lamotte Sandstone. It contained only about 105 ft of 12-in. diameter casing, and was not pressure-grouted. Liner, which is smaller diameter, light-weight casing, was installed through the Davis Formation to prevent shale from caving into the well. It produced about 420 gpm when first drilled, but production eventually dropped to about 350 gpm. The well was abandoned and plugged in 1966. When drilled, static water level was 228 ft, and in 1966, prior to plugging, was 237 ft.

City of Rolla, Well #2

Well #2 was drilled in 1934 and 1935, and at a total depth of 1,745 ft is the deepest of the City wells. The well was completed with 395 feet of 12-in. diameter casing, but was recased in 1956 with 494 ft of 10-in. diameter casing set into the Lower Gasconade Dolomite. Because the well was drilled through the Davis Formation, 8-in. diameter liner was installed from 1,250 ft to 1,450 ft to prevent shale from caving into the well bore.

When drilled, well #2 had a production of 415 gpm, a static water level of 235 ft below land surface, and a specific capacity of 14.6 gpm/ft. Production has decreased substantially since 1935. It currently produces about 180 gpm, has a static water level of about 400 feet, and a specific capacity of 4.0 gpm/ft. In the 34 year period between March, 1957, and January, 1992, well #2 has produced about 714 million gallons, and has provided 3.71 percent of the water used by City of Rolla (tables 1 and 2). Water level declined an average of 2.9 ft/year since 1935, and 3.5 ft/year since 1957.

City of Rolla, Well #3

Well #3, constructed in 1942, is 1,175 feet deep and contains 392 ft of 10-in. diameter casing set through the Upper Gasconade Dolomite. It produces from the Lower Gasconade, Eminence, and Potosi dolomites. The well currently produces about 470 gpm. Specific capacity of the well when it was drilled was 10.7 gpm/ft, somewhat less than that of well #2. However, specific capacity of well #3 in 1990 was 12.3 gpm/ft, and unlike well #2 specific capacity has increased slightly.

From 1957 to 1991, well #3 produced about 1,872 million gallons, and supplied about 9.7 percent of the water produced by the City during that period. From 1957 to 1960, it supplied between 21 percent and 26 percent of the total production (tables 3 and 4).

When drilled, static water level in well #3 was 245 ft. In July, 1992, static water level was 420 feet. Total water-level decline at the well since 1942 has been about 175 ft, an average of 3.5 ft/yr. Static water level data are not available for the years 1957 to 1967, but average water-level decline since 1967 has averaged 3.13 ft/yr.

City of Rolla, Well #4

Construction of wells #4 and #5 in 1946 and 1947 more than doubled water-production capability for Rolla. Well #4 was drilled in 1946 and 1947 to a depth of 1,078

ft and contains 232 ft of 12-in. diameter casing set into the Upper Gasconade Dolomite. When new, the well produced about 510 gpm and had a specific capacity of 6.8 gpm/ft. Production has not decreased substantially over the years; in 1990 the well produced 535 gpm. Specific capacity, however, has decreased to 3.9 gpm/ft.

From 1957 to 1991, well #4 produced 1,896 million gallons, supplying 9.85 percent of the total volume of

water produced by the City during that period (tables 5 and 6). In 1958 and 1959, it provided about 20 percent of the City's supply, but in 1990 accounted for only 5.1 percent of the water produced by the City.

Water level in well #4 has declined about 160 ft since 1947. In July, 1992, static water level was 325 ft; static water level in 1947 was 165 ft. Yearly water-level decline has averaged about 3.6 ft/yr.

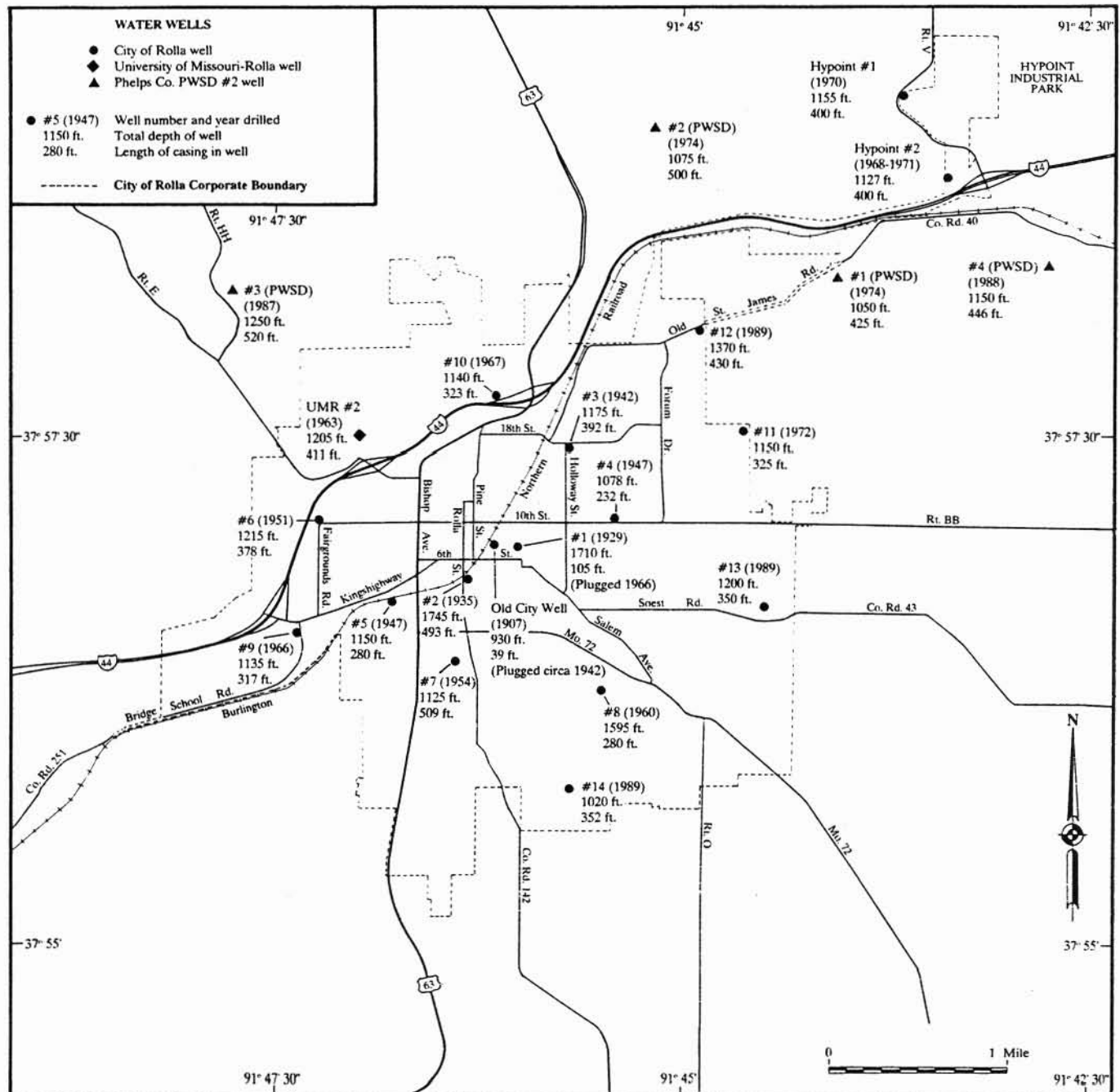


Figure 3: Location and construction information, City of Rolla, University of Missouri-Rolla, and Phelps County PWSD #2 wells.

City of Rolla, Well #5

Drilled in 1947, well #5 is 1,150 ft deep and contains 280 ft of 12-inch diameter casing set into the Upper Gasconade Dolomite. The well was originally capable of producing about 580 gpm with about 50 ft of drawdown; specific capacity was 11.6 gpm/ft. In 1990, average production was 590 gpm, but specific capacity had decreased to 5.5 gpm/ft.

From 1957 to 1990, well #5 produced a total of 2,369 million gallons, supplying about 12.3 percent of the water produced by the City during that period (tables 7 and 8). From 1957 through 1964 it supplied about 20 percent of the water used by Rolla, but in 1990 it supplied less than 7 percent of the total production.

Static water level in well #5 has lowered from 245 ft in 1947 to 380 ft below land surface in July, 1992, a decline of 135 ft and an average annual decline of about 3 ft/yr.

City of Rolla, Well #6

Well #6, constructed in 1951, is 1,215 ft deep, and contains 378 ft of 12-in. diameter casing set into the Upper Gasconade Dolomite. When drilled, the well produced about 585 gpm with a specific capacity of 7.3 gpm/ft. By 1962, specific capacity had decreased to 5.7 gpm/ft and the well was producing 483 gpm. The well was acidized with 4,000 gallons of 15 percent hydrochloric acid in two stages. Afterwards, production increased to 524 gpm, and specific capacity to 7.5 gpm/ft. In 1990, it produced about 500 gpm, and had a specific capacity of 9.7 gpm/ft.

From 1957 to 1992, well #6 produced a total of 1,781 million gallons and for that period supplied 9.3 percent of the water used in Rolla (tables 9 and 10). From 1957 through 1960 it supplied about 20 percent of the total supply, but in 1990 accounted for only about 7.2 percent of the water produced. When drilled, static water level in well #6 was 315 ft below land surface. In July, 1992, static water level was 435 ft, a decline of 120 ft and average yearly decline of 2.9 ft/yr.

City of Rolla, Well #7

Drilled in 1954, well #7 is 1,125 ft deep and was cased into the Upper Gasconade Dolomite with 292 ft of 12-in. diameter casing. In 1958, the well was recased to 509 ft with 10-inch diameter casing, possibly due to water-quality problems. When drilled, its specific capacity was 2.8 gpm/ft and it yielded about 360 gpm. The well was acidized to increase production using 6,000 gallons of 15 percent hydrochloric acid. Yield and specific capacity

after acid treatment increased to 550 gpm, and 4.2 gpm/ft, respectively. Currently, the well produces about 400 gpm, and specific capacity has decreased to 3.1 gpm/ft.

From 1957 to 1991, well #7 produced about 1,557 million gallons of water, and supplied about 8.1 percent of the water used by Rolla during that period (tables 11 and 12). At most, it supplied 17.4 percent of the water needs, but in 1990 only provided 4.7 percent of the total production.

Static water level when the well was drilled was 240 ft. In July, 1992, static water level had declined to 355 ft. Water level decline at the well has averaged about 3 ft/yr.

City of Rolla, Well #8

Well #8, drilled in 1960, has the unfortunate distinction of being the City's poorest producing well. Production from the Lower Gasconade, Eminence, and Potosi Dolomites was low, so drilling continued through the Bonnetterre Formation in hopes of increasing the yield. The well was completed to a total depth of 1,595 ft, and cased into the Upper Gasconade Dolomite with 280 ft of 12-in. diameter casing. About 233 ft of 8-in. diameter liner was set through caving shales in the Davis Formation from a depth of 1,192 ft to 1,425 ft. The well initially produced about 150 gpm with a specific capacity of less than 1 gpm/ft. The well was acidized using about 4,000 gallons of 15 percent hydrochloric acid introduced into the well near the base of the Potosi Dolomite. After acid treatment, yield increased somewhat to 210 gpm with 130 ft of drawdown. Specific capacity increased to 1.6 gpm/ft. Well #8 is currently pumped at about 240 gpm and has a specific capacity of 1.3 gpm/ft.

From 1960 to 1991, total production of well #8 was 753 million gallons, and through that period supplied only 4.1 percent of the water used by Rolla (tables 13 and 14). In 1960, static water level at well #8 was 250 ft. In July, 1992, static water level was 280 ft, a decline of only 30 feet and an average annual decline of less than 1 ft/yr.

City of Rolla, Well #9

Well #9 was drilled in 1966 to a total depth of 1,135 ft, and is cased into the Upper Gasconade Dolomite with 317 ft of 12-in. diameter casing. When new, the well was tested at 800 gpm and had a specific capacity of 12.5 gpm/ft. Currently, the well is pumped at about 500 gpm, and specific capacity is 10.7 gpm/ft.

From August, 1966, through 1990, the well produced 1,815 million gallons, supplying about 11.1 percent of Rolla's total water supply through the period (tables 15

and 16). In 1990, it accounted for 6.2 percent of Rolla's production.

The log of well #9 shows a static water level of 348 ft. However, that value may not accurately reflect water level of the well when it was drilled. Records kept by RMU show static water level when drilled to be about 305 ft. In July, 1992, static water level was measured at 504 ft, indicating a water-level decline of 199 ft, and an average yearly decline of 7.6 ft/yr. However, water-level data for well #9 is poor due to problems with the air line in the well. Data are missing for much of the period between 1970 and 1980, and after 1988, so the above values may not be accurate.

University of Missouri-Rolla, Well #2

Prior to 1967, University of Missouri-Rolla operated their own water-supply system, with cross-connections to the City's supply. In 1963, UMR contracted for drilling of their third water-supply well. Completed to a depth of 1,205 ft and containing 309 ft of 12-in. diameter casing, this well, designated UMR well #2, yielded about 520 gpm and had a specific capacity of 6.0 gpm/ft. In 1967, the university and the City of Rolla entered into an agreement whereby the City would supply water to the university. University of Missouri-Rolla well #2 was leased by Rolla Municipal Utilities in 1970, and its production added to the City's system. In 1990, the well yielded about 570 gpm, and had a specific capacity of about 5.8 gpm/ft.

Production data are not available for the period prior to June, 1970, but between then and 1991, UMR well #2 produced 1,018 million gallons and supplied about 7.2 percent of Rolla's production (tables 17 and 18). The City still supplies UMR, but returned control of UMR well #2 to the university in July, 1990. Since then, Rolla Municipal Utilities has removed their pump from the well. Presently, the U.S. Geological Survey uses the well as a groundwater-level observation well and has equipped it with a digital water-level recorder.

In 1964, UMR well #2 had a static water level of 361 ft. In July, 1992, static water level was 421 ft. Water-level decline at the well is 60 feet, or about 2.1 ft/yr.

City of Rolla, Well #10

Well #10, completed in 1967, has a total depth of 1,140 ft and bottoms in the Derby-Doerun Dolomite. It contains 323 ft of 12-in. diameter casing set into the Upper Gasconade Dolomite. Initial production was apparently inadequate, so the well was acidized using 1000 gallons of hydrochloric acid. After acid treatment, the well

yielded 524 gpm with a specific capacity of 6.0 gpm/ft. In 1990, the well was pumped at an average 610 gpm and had a specific capacity of 9.4 gpm/ft.

Between July, 1967, and 1991, well #10 produced about 1,669 million gallons, supplying 10.5 percent of Rolla's production (tables 19 and 20). In 1990, it provided about 8 percent of the water used.

When it was drilled, static water level was 295 ft. In July, 1992, static water level was 470 ft, a decline of 175 ft. Average yearly decline is about 7 ft/yr.

Hypoint Industrial Park Wells #1 and #2

In 1968 and 1970, three water-supply wells were drilled to supply the Hypoint Industrial Park. Ultimately, two of the wells, Hypoint #1 and #2, were completed as water-supply wells. The third, Hypoint well #3, was completed, but has been used since as a groundwater-level observation well. Hypoint wells #1 and #2 have excellent yields and specific capacities. Hypoint well #1 is 1,155 ft deep and is cased into the Upper Gasconade Dolomite with 400 ft of 12-in. diameter casing. It currently produces about 980 gpm, and when drilled had a specific capacity of 27.8 gpm/ft. Hypoint well #2 was drilled to a depth of 650 ft through the Lower Gasconade Dolomite in 1968, and cased with 400 ft of 12-in. diameter casing into the Upper Gasconade Dolomite. Yield was low, 88 gpm with 200 ft of drawdown and a specific capacity of 0.44 gpm/ft. It was acidized to bring production up to 125 gpm with 80.6 ft of drawdown, and specific capacity increased to 1.5 gpm/ft. Finally, the well was deepened in 1971 to 1,127 ft, through the Potosi Dolomite, which increased the yield to 500 gpm with 78 ft of drawdown. Specific capacity after deepening was 6.4 gpm/ft.

From 1975 through 1990, Hypoint well #1 produced about 1,063 million gallons of water, about 9.2 percent of Rolla's total production (tables 21 and 22). During the same periods, Hypoint well #2 produced 1,005 million gallons, about 8.7 percent of the total production (tables 23 and 24).

Static water-level data are not sufficient to develop long-term hydrographs for Hypoint wells #1 and #2. Both wells are equipped with air lines and gages, and water levels are measured at both wells. However, unlike the other city wells where pumps are started and stopped manually, the Hypoint well pumps start and stop automatically, depending on pressure in the system. Thus, some water-level measurements are made while the pumps are running, and some when the pumps are off. Still, there are adequate data to show water-level decline characteristics for the wells. When both wells were

drilled, static water levels were about 250 ft below land surface. In August, 1992, static water levels at Hypoint wells #1 and #2 were 300 ft and 250 ft, respectively, showing there has been relatively minor water-level decline in the Ozark aquifer in the Hypoint Industrial Park area between about 1970 and the present.

Hypoint well #3, drilled in 1968, is 800 ft deep and contains 400 ft of 8-in. diameter casing set into the Upper Gasconade Dolomite. The well may have been used briefly for water supply, but since 1975 has been used as a groundwater-level observation well operated by DGLS. Water-level data from it shows that pumping from the other Hypoint wells causes temporary water-level declines, but recovery is rapid, and the net decline in water level in the area since the early 1970s is minimal.

City of Rolla, Well #11

Well #11 was drilled in 1972. It was the last production well constructed by the City until 1989, and is one of the City's highest producing wells. Well #11 is pumped at about 950 gpm, and has a specific capacity of 12.3 gpm/ft. When drilled, it was pump-tested at 868 gpm and had a specific capacity of 11.2 gpm/ft. Its total depth is 1,150 ft and it contains 325 ft of 12-in. diameter casing set into the Upper Gasconade Dolomite.

From November, 1972, through 1990, well #11 produced 1,571 million gallons accounting for 12.2 percent of the City's production during that time period (tables 25 and 26). In 1989, it provided 17.5 percent of water produced by the City.

When drilled, well #11 had a static water level of 294 ft. In July, 1992, static water level was 350 ft. Water-level decline is about 56 ft since 1972, an average of about 2.8 ft/yr.

City of Rolla Wells #12 and #13

Wells #12 and #13 were completed in 1989. Well #12 was drilled to a depth of 1,370 ft and contains 430 ft of 14-in. diameter casing set a few feet below the base of the Upper Gasconade Dolomite. Well #13 is 1,200 ft deep and cased with 350 ft of 14-in. diameter casing into the Lower Gasconade Dolomite. There are significant differences in production characteristics between the two wells. Well #12 currently produces about 580 gpm and has a specific capacity of 2.8 gpm/ft. Well #13 yields 990 gpm, and its specific capacity when drilled was 9.1 gpm/ft. Production from both wells was added to Rolla's water-supply system beginning early 1990. Production information is shown in tables 27 and 28 for well #12, and tables 29 and 30 for well #13. Well #12 provided

10.4 percent of Rolla's water in 1990, and well #13 provided 12.4 percent.

Static water levels for wells #12 and #13 in July, 1992, were 375 ft and 235 ft, respectively. When drilled, static water level at well #12 was 330 ft; at well #13 it was about 210 ft.

City of Rolla Well #14

Well #14 was drilled in 1982 by a private developer to supply Oak Knolls subdivision, and was then known as Oak Knolls well #2. The well was purchased by the City when the subdivision was annexed. Well #14 is 1,020 ft deep and contains 352 ft of 8-in. diameter casing set through the Upper Gasconade Dolomite. The log of the well shows a yield of 450 gpm; specific capacity data are not available. When drilled, static water level at the well was about 250 ft. In July, 1992, static water level was 349 ft. The well is not currently used by the City.

PHELPS COUNTY PWSD #2 WELLS

Phelps County PWSD #2 constructed its first two wells in 1974, and began supplying water in 1975. Wells #3 and #4 were added in 1987 and 1988, respectively. In July, 1992, the district had 496 active customers including 15 to 20 businesses. Most of the produced water is used for domestic water supply, and annual production currently is about 40 million gallons. Figure 4 shows monthly production for 1982 to 1991 for the District's 4 wells.

The water district wells are quite similar in depth and construction to Rolla's wells. All are cased into the Upper Gasconade Dolomite, and produce from the Lower Gasconade, Eminence, and Potosi dolomites.

Well #1 is 1,050 ft deep and contains 425 ft of 8-in. diameter casing. Static water level at the time of drilling was 298 ft. In July, 1992, static water level was 332 ft, a decline of about 34 feet in 18 years or an average decline of about 1.9 ft/yr. Specific capacity of the well is about 14.6 gpm/ft. From 1982 through 1990, well #1 produced 171 million gallons, and has been the District's most heavily pumped well. It has produced about 53 percent of the District's water during the period of record. Currently, the well is pumped at about 180 gpm.

Well #2 is 1,075 ft deep and contains 500 ft of 10-in. diameter casing. Water level at the time of drilling was 301.5 ft, and in July, 1992, was 340 ft. Water-level decline over the 18 years was about 38.5 ft, or an average of about 2.1 ft/yr. The well was tested at a pumping rate of 250 gpm, and had 12.4 ft of drawdown; specific capacity of the well is

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #2
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.31	0.51	0.50	0.31	0.00	0.00	0.00	1.42	1.24	0.93	5.23
1958	0.59	1.35	1.06	1.29	0.81	0.81	0.12	0.00	1.24	2.50	2.28	1.57	13.63
1959	1.04	1.62	2.00	2.77	1.57	1.55	1.27	0.70	1.92	0.49	0.79	1.29	17.00
1960	0.77	1.88	1.29	2.29	1.79	1.82	2.14	1.67	2.78	2.00	1.53	1.60	21.55
1961	0.83	1.66	1.08	1.62	2.04	1.75	2.56	4.25	2.72	2.69	3.01	2.08	26.28
1962	2.83	1.57	2.28	2.16	3.47	1.29	2.08	1.06	2.04	2.10	1.49	1.16	23.52
1963	0.78	1.33	2.02	2.52	2.30	1.70	3.25	1.24	2.08	2.55	1.76	0.85	22.38
1964	1.38	1.84	2.83	2.54	2.43	2.21	1.92	2.30	1.95	2.05	1.16	1.66	24.27
1965	1.85	2.84	2.38	1.31	2.34	2.34	1.89	2.42	2.52	2.45	4.30	3.86	30.52
1966	3.89	2.66	2.21	1.73	2.26	1.97	3.12	0.75	1.09	0.78	2.74	2.82	26.01
1967	0.52	1.73	1.62	2.85	2.30	1.87	2.07	1.39	2.12	1.53	1.43	2.61	22.04
1968	1.16	0.63	1.13	0.34	1.92	2.13	2.09	1.33	1.41	2.26	2.14	1.50	18.07
1969	0.49	2.63	1.42	1.69	2.48	1.42	3.44	3.13	3.06	2.85	2.40	3.44	28.46
1970	2.61	2.80	2.37	2.66	3.29	2.50	2.08	2.14	2.58	1.94	3.10	2.32	30.38
1971	2.27	2.35	2.46	2.64	3.11	2.42	3.43	3.33	3.50	2.75	2.82	2.53	33.60
1972	1.66	2.48	2.50	2.42	2.88	2.66	2.93	2.42	2.47	2.22	2.68	2.30	29.61
1973	2.37	2.22	2.29	1.08	1.60	1.45	1.85	1.93	1.90	2.00	1.52	2.05	22.25
1974	1.89	1.56	1.85	1.53	1.93	2.25	2.18	2.00	1.89	2.14	1.89	2.13	23.24
1975	2.10	1.27	0.98	0.62	1.32	1.88	1.85	2.01	1.85	1.45	0.67	2.15	18.14
1976	1.35	1.43	1.72	1.57	0.87	2.10	1.84	2.09	1.91	1.66	1.67	1.77	19.97
1977	1.75	1.72	1.79	1.61	1.35	1.75	1.94	1.72	1.46	1.71	1.49	0.84	19.14
1978	1.53	1.11	1.54	1.77	1.84	1.66	2.00	1.84	2.01	1.64	2.25	2.02	21.20
1979	1.63	1.78	1.99	1.60	2.01	1.98	2.14	1.85	1.58	1.76	1.98	2.29	22.59
1980	3.97	3.05	3.56	3.13	1.55	1.65	0.00	0.00	0.00	0.00	0.00	0.00	16.90
1981	2.81	1.98	2.72	1.88	2.63	2.55	2.57	2.89	3.01	2.46	2.22	2.89	30.61
1982	2.12	3.08	2.27	2.20	1.89	2.42	2.12	2.05	2.59	2.27	2.75	1.84	27.58
1983	2.15	1.86	2.17	1.61	2.44	1.19	1.56	2.12	1.96	1.23	1.33	2.06	21.69
1984	1.76	1.46	1.67	1.76	1.31	1.65	1.96	2.11	1.79	1.86	2.20	1.39	20.92
1985	2.20	1.99	2.05	1.95	1.90	1.72	1.64	1.56	1.52	2.55	1.09	1.55	21.72
1986	1.99	1.58	1.53	0.69	1.23	1.44	1.33	1.34	1.21	1.74	1.52	2.15	17.75
1987	1.02	2.02	0.90	1.81	1.57	1.40	1.88	1.59	1.75	1.36	1.66	1.23	18.19
1988	1.87	2.38	2.39	1.82	2.55	1.46	1.61	2.03	1.22	1.97	0.00	0.00	19.29
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.60
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL													
MONTHLY PRODUCTION	55.19	59.86	60.36	57.98	63.48	57.33	63.45	57.24	61.13	60.35	59.10	58.88	

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #2: 714.3354 MILLION GALLONS

Table 1: Monthly and yearly production, City of Rolla, well #2, 1957-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	1.72	2.41	2.39	1.24	0.00	0.00	0.00	6.35	5.77	4.59	2.09
1958	3.02	6.05	5.38	6.07	3.92	3.56	0.56	0.00	4.94	10.32	9.94	7.26	5.12
1959	4.95	7.16	9.65	11.99	6.39	5.36	4.28	2.22	7.14	1.90	3.14	5.75	5.63
1960	3.54	8.52	6.14	9.63	7.63	7.06	7.59	6.54	10.26	7.82	6.30	7.32	7.43
1961	3.69	6.99	5.72	6.92	8.73	9.13	10.55	15.80	10.23	10.29	12.26	9.66	9.36
1962	12.08	6.13	10.08	8.05	11.73	4.70	6.75	3.22	7.01	8.04	6.00	4.81	7.28
1963	3.29	4.96	8.73	9.50	8.73	6.15	11.19	4.43	7.30	7.76	6.39	3.58	6.91
1964	5.48	7.31	11.72	9.54	8.75	7.90	5.97	6.37	5.87	6.72	3.81	6.51	7.04
1965	7.12	10.51	9.64	4.89	6.85	7.99	5.52	7.32	8.72	7.74	13.48	13.41	8.56
1966	13.57	8.57	7.58	5.33	7.08	5.69	5.87	1.99	3.04	1.96	7.81	8.92	6.18
1967	1.64	5.22	5.27	8.20	6.99	5.67	5.34	3.05	4.43	3.62	3.50	6.94	4.91
1968	2.98	1.56	2.89	0.83	4.36	4.98	4.06	2.85	2.79	4.78	4.64	3.82	3.42
1969	1.28	6.34	3.60	3.89	5.44	3.16	6.95	6.29	6.72	6.22	5.11	8.05	5.33
1970	6.23	6.08	5.48	5.74	6.74	5.19	3.62	3.78	4.43	3.87	6.34	5.05	5.13
1971	5.38	4.70	5.60	5.23	6.05	4.74	5.33	5.63	5.68	5.42	5.71	5.66	5.43
1972	4.52	5.40	5.33	5.34	6.08	4.70	4.93	4.28	4.60	4.39	5.39	5.00	4.98
1973	4.85	4.91	4.82	2.38	3.49	3.06	3.25	3.33	3.35	4.14	3.00	4.84	3.75
1974	4.22	3.91	4.35	3.58	4.53	5.19	3.59	3.36	3.68	4.80	4.07	5.17	4.15
1975	4.43	2.54	1.88	1.38	2.63	3.39	2.76	3.12	2.91	2.39	1.17	3.86	2.71
1976	2.50	2.66	3.02	2.94	1.59	3.64	2.88	3.21	2.60	2.49	2.65	3.01	2.77
1977	2.71	2.60	2.99	2.76	2.16	2.74	3.42	2.74	2.38	3.05	2.48	1.60	2.64
1978	3.01	2.18	3.04	3.11	3.52	2.98	3.05	3.22	2.89	2.71	3.80	3.67	3.10
1979	2.92	3.27	3.25	2.93	3.11	3.50	3.43	2.83	2.43	2.62	3.35	3.63	3.10
1980	7.04	5.65	6.26	5.59	2.84	2.78	0.00	0.00	0.00	0.00	0.00	0.00	2.28
1981	4.85	3.58	4.36	3.46	4.10	4.14	4.15	5.04	4.40	3.85	3.70	4.54	4.19
1982	3.69	4.52	3.83	3.77	2.91	3.82	3.47	2.76	3.26	3.57	4.04	3.21	3.56
1983	3.80	3.31	3.61	3.01	3.98	1.97	2.10	2.25	2.76	1.92	2.26	3.53	2.82
1984	2.89	2.66	2.82	3.07	2.19	2.78	2.98	2.83	2.69	3.16	3.97	2.64	2.89
1985	3.92	3.71	3.66	3.30	3.28	3.32	2.18	2.47	2.12	3.88	1.94	2.77	3.01
1986	3.69	3.12	2.66	1.22	2.15	2.37	1.90	2.03	1.73	2.80	2.86	3.78	2.48
1987	2.01	3.73	1.47	3.07	2.90	2.08	2.89	2.25	2.59	2.24	2.84	2.27	2.52
1988	3.57	4.08	4.22	3.26	3.61	1.87	2.82	2.87	1.94	3.28	0.00	0.00	2.65
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.08
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
* TOTAL													
MONTHLY	3.86	4.07	4.07	3.89	4.03	3.56	3.51	3.12	3.39	3.60	3.73	3.95	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #2: 3.71 PERCENT

Table 2: Percentage of total monthly and yearly production provided by City of Rolla, well #2.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #3
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	4.37	4.32	5.42	5.56	6.24	6.53	6.59	8.50	5.25	4.06	4.03	60.88
1958	4.57	5.71	4.23	4.78	4.55	4.45	4.43	6.28	5.67	6.35	6.04	5.23	62.29
1959	5.76	6.14	5.03	5.02	6.59	6.55	8.20	8.93	6.96	6.68	6.58	6.36	78.79
1960	5.51	4.66	5.03	4.24	4.75	6.62	5.96	4.81	5.88	4.65	4.26	3.95	60.33
1961	4.22	4.87	3.14	4.31	3.86	4.67	3.91	4.44	4.02	4.80	4.37	4.27	50.88
1962	4.99	4.79	4.47	4.09	6.41	5.62	6.40	7.11	5.03	5.43	4.40	4.79	63.53
1963	4.31	5.17	4.28	4.55	4.42	4.98	4.84	5.37	4.94	7.00	4.78	4.20	58.84
1964	4.72	5.11	4.32	5.29	4.45	6.03	7.62	7.54	5.17	6.22	5.73	5.15	67.35
1965	5.72	4.34	4.13	4.71	6.08	6.81	6.32	8.04	7.65	6.26	7.99	8.03	76.08
1966	6.25	6.92	4.21	6.50	6.27	6.56	10.52	9.28	5.50	7.80	8.20	5.36	83.38
1967	5.02	5.12	6.02	6.43	5.11	4.96	5.15	1.24	5.73	7.01	4.29	4.13	60.21
1968	5.57	7.08	6.01	5.57	5.96	4.80	6.45	3.42	7.76	6.52	8.09	5.47	72.70
1969	6.34	5.32	6.62	7.40	5.92	5.55	6.81	7.90	5.90	6.98	7.27	6.30	78.31
1970	5.98	7.82	6.23	6.65	6.57	5.23	5.61	6.24	5.31	5.33	4.14	4.39	69.49
1971	4.19	4.48	4.37	4.26	4.24	4.06	6.49	6.46	5.53	4.27	4.24	3.69	56.27
1972	2.60	4.22	4.30	4.48	4.41	4.88	5.82	5.14	4.50	4.16	3.59	4.08	52.18
1973	4.87	4.47	4.37	4.34	3.97	3.69	4.29	4.64	4.65	4.43	4.94	3.68	52.34
1974	4.08	3.01	3.57	4.81	3.77	4.29	4.21	5.60	4.21	3.65	4.47	3.90	49.58
1975	4.80	3.41	5.57	4.30	3.86	5.62	1.78	2.35	4.13	4.56	4.91	4.04	49.31
1976	4.03	4.90	4.50	3.75	3.15	0.63	1.77	3.50	3.70	5.36	3.24	3.72	42.24
1977	3.87	4.78	3.91	4.14	4.18	4.31	3.57	6.26	4.29	4.06	3.41	4.54	51.33
1978	1.84	3.49	3.88	3.82	3.21	0.00	0.00	5.53	7.29	4.33	4.07	3.98	41.45
1979	4.80	4.49	3.98	3.72	4.82	4.51	4.45	4.51	4.68	4.02	4.20	4.15	52.35
1980	4.02	3.44	3.87	3.81	3.25	4.03	4.05	3.67	5.26	5.34	4.42	4.84	49.99
1981	3.80	3.42	3.32	3.32	2.08	3.62	4.48	3.64	4.25	3.36	3.95	3.57	42.82
1982	3.39	3.18	2.71	3.18	3.15	1.11	1.49	3.04	3.21	3.94	3.47	2.89	34.77
1983	3.61	3.33	3.72	3.82	4.10	4.93	4.69	4.51	4.54	2.76	4.36	3.52	47.88
1984	3.14	2.75	5.49	5.73	4.96	4.90	4.83	4.64	2.78	2.83	2.04	2.54	46.63
1985	3.95	3.28	3.70	4.57	4.34	4.64	3.74	4.13	3.98	2.03	0.00	3.67	42.03
1986	4.10	4.51	5.23	4.09	4.02	4.74	5.17	4.45	4.98	4.45	2.50	3.68	51.92
1987	2.22	2.70	3.03	3.02	3.52	3.87	2.89	3.35	4.28	2.98	2.59	2.69	37.13
1988	2.71	3.28	3.62	3.23	3.56	2.18	0.00	0.00	0.00	0.00	0.00	0.00	18.58
1989	0.00	4.05	4.37	4.68	6.90	8.39	8.76	6.69	6.91	6.13	5.21	1.15	63.23
1990	5.19	3.77	3.41	3.58	4.55	3.93	3.46	5.22	4.99	3.56	3.84	1.48	46.99
TOTAL													
MONTHLY	140.18	152.37	148.96	155.62	156.52	157.39	164.70	174.53	172.20	162.51	149.66	137.47	
PRODUCTION													

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #3: 1872.113 MILLION GALLONS

Table 3: Monthly and yearly production, City of Rolla, well #3, 1957-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	21.98	23.93	25.39	26.76	25.00	24.89	23.55	32.49	23.49	18.86	19.80	24.39
1958	23.38	25.66	21.42	22.38	22.04	19.47	19.96	26.34	22.53	26.22	26.33	24.19	23.39
1959	27.37	27.18	24.33	21.70	26.85	22.57	27.50	28.52	25.86	26.15	26.31	28.45	26.10
1960	25.44	21.09	23.93	17.88	20.27	25.62	21.13	18.90	21.74	18.15	17.61	18.02	20.79
1961	18.85	20.50	16.60	18.43	16.52	24.27	16.14	16.50	15.10	18.40	17.83	19.89	18.11
1962	21.31	18.75	19.78	15.27	21.66	20.41	20.75	21.69	17.29	20.82	17.69	19.94	19.66
1963	18.19	19.35	18.52	17.17	16.74	18.00	16.67	19.17	17.34	21.26	17.39	17.55	18.16
1964	18.73	20.30	17.91	19.88	16.02	21.58	23.71	20.91	15.56	20.39	18.75	20.15	19.53
1965	21.96	16.02	16.72	17.55	17.77	23.23	18.45	24.31	26.49	19.78	25.06	27.90	21.33
1966	21.81	22.26	14.43	19.99	19.65	18.96	19.81	24.52	15.39	19.59	23.38	16.98	19.80
1967	15.87	15.51	19.55	18.51	15.53	15.02	13.31	2.72	11.97	16.58	10.52	10.97	13.41
1968	14.26	17.48	15.35	13.45	13.54	11.19	12.53	7.34	15.33	13.78	17.49	13.92	13.75
1969	16.39	12.84	16.75	16.98	13.01	12.30	13.77	15.86	12.96	15.25	15.45	14.74	14.66
1970	14.27	16.98	14.43	14.37	13.48	10.83	9.79	11.01	9.11	10.61	8.47	9.55	11.74
1971	9.92	8.96	9.97	8.45	8.24	7.97	10.08	10.94	8.96	8.41	8.61	8.26	9.09
1972	7.11	9.19	9.17	9.88	9.30	8.61	9.80	9.09	8.39	8.24	7.20	8.88	8.78
1973	9.94	9.87	9.19	9.61	8.62	7.80	7.54	8.02	8.20	9.16	9.79	8.71	8.83
1974	9.11	7.56	8.41	11.25	8.83	9.88	6.94	9.42	8.19	8.21	9.62	9.45	8.86
1975	10.12	6.82	10.68	9.52	7.71	10.10	2.66	3.64	6.48	7.53	8.59	7.27	7.38
1976	7.45	9.11	7.93	7.02	5.77	1.09	2.77	5.36	5.05	8.05	5.14	6.34	5.86
1977	5.99	7.26	6.53	7.08	6.71	6.74	6.28	9.94	6.98	7.25	5.67	8.69	7.08
1978	3.64	6.84	7.68	6.72	6.12	0.00	0.00	9.68	10.50	7.18	6.88	7.25	6.06
1979	8.58	8.23	6.50	6.83	7.47	7.98	7.14	6.90	7.20	6.01	7.10	6.58	7.18
1980	7.13	6.36	6.80	6.82	5.95	6.78	4.96	4.98	7.93	7.91	7.42	8.71	6.74
1981	6.57	6.18	5.34	6.11	3.24	5.87	7.24	6.36	6.21	5.25	6.57	5.62	5.86
1982	5.92	4.66	4.59	5.47	4.85	1.76	2.43	4.10	4.05	6.19	5.11	5.05	4.49
1983	6.38	5.92	6.18	7.13	6.66	8.20	6.31	4.78	6.38	4.32	7.43	6.02	6.23
1984	5.15	5.03	9.27	9.99	8.30	8.25	7.34	6.24	4.20	4.82	3.68	4.80	6.43
1985	7.03	6.13	6.63	7.73	7.47	8.96	4.97	6.55	5.55	3.09	0.00	6.54	5.82
1986	7.59	8.89	9.08	7.23	7.04	7.80	7.41	6.73	7.13	7.18	4.72	6.46	7.27
1987	4.37	4.97	4.97	5.11	6.51	5.75	4.44	4.76	6.34	4.92	4.41	4.96	5.13
1988	5.19	5.63	6.39	5.79	5.04	2.79	0.00	0.00	0.00	0.00	0.00	0.00	2.55
1989	0.00	8.09	7.85	8.70	10.32	14.38	12.47	9.49	10.95	8.71	8.59	1.91	8.59
1990	8.21	7.27	5.43	6.33	7.81	6.33	5.47	7.74	7.15	5.66	7.03	2.61	6.44
% TOTAL													
MONTHLY	9.80	10.36	10.04	10.44	9.94	9.79	9.10	9.53	9.55	9.71	9.45	9.23	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #3: 9.73 PERCENT

Table 4: Percentage of total monthly and yearly production provided by City of Rolla, well #3.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #4
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	4.95	4.62	4.88	5.27	5.61	6.38	6.26	1.12	2.08	3.57	4.21	48.95
1958	4.16	4.92	3.72	3.61	3.69	3.89	4.89	5.78	5.84	4.36	4.73	4.13	53.72
1959	4.72	4.77	4.16	4.75	5.43	6.90	6.23	5.86	5.20	4.90	5.32	3.78	62.03
1960	4.16	3.56	3.15	3.67	2.66	0.00	5.11	4.51	3.76	3.69	3.46	3.83	41.58
1961	4.29	3.64	2.91	3.51	3.05	0.00	3.65	3.99	4.12	4.15	3.28	3.11	39.70
1962	3.09	3.80	3.74	3.97	4.27	4.65	4.92	5.49	5.61	3.58	3.76	3.73	50.60
1963	3.54	3.96	3.61	4.21	3.65	5.21	4.02	4.17	4.84	6.01	4.36	3.30	50.90
1964	3.62	4.01	3.91	3.63	4.57	4.00	4.46	5.68	6.19	4.79	4.55	4.15	53.56
1965	3.79	3.93	3.86	4.14	6.09	4.61	5.09	4.59	3.65	5.73	5.54	3.93	54.96
1966	6.15	6.37	4.38	4.15	6.86	7.41	11.20	12.88	6.76	8.53	9.06	5.74	89.48
1967	7.13	4.92	4.43	5.48	5.72	6.42	6.39	7.27	6.78	7.27	5.46	6.63	73.91
1968	5.97	6.49	7.27	7.49	6.03	8.36	9.25	8.02	9.56	8.80	8.77	8.07	94.08
1969	8.70	9.00	9.49	8.04	9.34	9.25	8.52	6.13	6.08	6.79	7.84	6.04	95.22
1970	6.68	6.09	6.29	7.05	6.80	6.37	5.83	5.38	5.44	5.44	5.44	5.44	72.24
1971	6.09	5.21	4.59	6.37	5.78	6.51	7.24	7.53	7.78	6.51	5.99	5.17	74.77
1972	4.61	5.46	5.66	6.00	5.28	6.78	5.76	6.02	6.28	6.61	5.12	5.70	69.28
1973	4.91	3.86	2.28	4.24	2.79	1.74	5.22	4.50	4.58	3.02	3.35	2.50	43.01
1974	5.32	3.64	2.01	2.73	2.77	2.91	5.81	5.82	4.07	4.51	3.04	2.44	45.06
1975	2.44	3.95	6.22	4.96	4.92	4.75	6.71	5.74	5.93	4.78	4.85	3.89	59.14
1976	4.38	3.35	3.36	3.37	2.10	3.36	4.71	4.64	6.48	5.06	2.80	2.97	46.58
1977	5.47	4.10	3.71	2.90	3.98	5.91	5.59	4.65	6.31	6.63	2.82	4.09	56.16
1978	5.72	2.18	3.92	3.39	2.14	0.00	0.00	0.00	0.00	5.96	5.02	3.35	31.68
1979	2.10	4.24	4.37	4.58	4.11	3.46	4.37	5.02	3.42	6.86	4.06	2.89	49.48
1980	2.50	2.95	4.08	3.44	3.85	4.82	7.78	10.53	6.49	5.98	4.83	2.82	60.07
1981	2.87	1.06	1.72	3.69	5.69	4.52	5.59	4.16	4.99	3.76	2.11	1.60	41.77
1982	1.66	3.86	2.09	2.25	1.58	3.11	1.99	4.28	4.06	4.51	3.51	3.36	36.28
1983	2.30	3.02	2.34	2.54	4.08	3.37	4.86	5.87	6.02	4.18	3.30	2.63	44.51
1984	4.92	1.64	1.64	2.57	2.99	3.50	3.70	6.32	6.19	3.30	2.68	2.23	41.68
1985	1.09	2.55	2.25	2.72	2.57	5.50	6.57	6.46	7.97	8.66	3.85	4.22	54.43
1986	3.87	3.26	5.47	3.34	4.69	4.94	6.08	4.92	5.81	4.50	3.35	3.60	53.84
1987	2.20	0.13	3.40	3.32	3.91	5.30	5.29	7.99	3.30	5.45	4.14	4.29	48.74
1988	3.69	5.72	5.35	5.50	5.77	6.51	4.14	7.86	6.38	5.19	5.23	5.21	66.53
1989	4.50	0.00	0.00	0.00	4.47	4.39	7.43	7.56	7.43	7.37	5.30	6.24	54.70
1990	7.06	3.21	4.91	3.74	4.30	4.60	3.74	2.91	0.00	0.00	0.00	3.01	37.49
TOTAL													
MONTHLY	143.72	133.83	134.92	140.23	151.22	158.69	188.53	198.81	178.46	178.97	150.48	138.30	
PRODUCTION													

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #4: 1896.152 MILLION GALLONS

Table 5: Monthly and yearly production, City of Rolla, well #4, 1957-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	24.87	25.62	22.87	25.37	22.45	24.33	22.35	4.27	9.29	16.62	20.67	19.61
1958	21.26	22.13	18.84	16.91	17.89	17.04	22.03	24.27	23.19	17.99	20.62	19.09	20.17
1959	22.44	21.12	20.11	20.54	22.12	23.79	20.91	18.72	19.33	19.18	21.27	16.91	20.54
1960	19.19	16.14	14.99	15.49	11.34	0.00	18.12	17.74	13.91	14.42	14.29	17.46	14.33
1961	19.18	15.33	15.43	14.99	13.02	0.00	15.06	14.83	15.47	15.91	13.36	14.46	14.13
1962	13.20	14.88	16.54	14.80	14.43	16.90	15.94	16.76	19.28	13.72	15.09	15.53	15.66
1963	14.98	14.80	15.62	15.90	13.83	18.82	13.84	14.88	17.00	18.28	15.87	13.82	15.71
1964	14.35	15.95	16.19	13.63	16.45	14.33	13.88	15.74	18.65	15.69	14.88	16.24	15.53
1965	14.55	14.51	15.64	15.43	17.82	15.71	14.86	13.88	12.63	18.12	17.37	13.66	15.41
1966	21.46	20.48	15.00	12.78	21.49	21.41	21.09	34.01	18.93	21.41	25.82	18.17	21.25
1967	22.56	14.89	14.40	15.75	17.39	19.46	16.52	15.93	14.17	17.19	13.39	17.62	16.46
1968	15.28	16.04	18.56	18.09	13.70	19.50	17.95	17.23	18.88	18.60	18.98	20.52	17.80
1969	22.49	21.73	24.01	18.44	20.52	20.49	17.23	12.31	13.36	14.82	16.67	14.12	17.82
1970	15.95	13.23	14.57	15.24	13.94	13.20	10.18	9.49	9.34	10.84	11.12	11.83	12.21
1971	14.45	10.42	10.47	12.64	11.24	12.77	11.24	12.76	12.61	12.82	12.14	11.58	12.09
1972	12.60	11.88	12.07	13.23	11.14	11.97	9.69	10.64	11.69	13.10	10.29	12.42	11.65
1973	10.04	8.52	4.80	9.39	6.07	3.68	9.18	7.77	8.08	6.26	6.63	5.92	7.25
1974	11.88	9.13	4.73	6.39	6.49	6.71	9.58	9.79	7.92	10.14	6.52	5.91	8.05
1975	5.15	7.92	11.93	10.97	9.83	8.54	10.03	8.92	9.31	7.89	8.48	7.00	8.85
1976	8.09	6.23	5.91	6.31	3.86	5.84	7.38	7.11	8.85	7.61	4.44	5.06	6.46
1977	8.46	6.23	6.20	4.96	6.40	9.25	9.83	7.37	10.26	11.82	4.68	7.82	7.75
1978	11.27	4.28	7.77	5.96	4.09	0.00	0.00	0.00	0.00	9.89	8.48	6.10	4.63
1979	3.76	7.78	7.13	8.41	6.37	6.11	7.03	7.68	5.25	10.24	6.86	4.57	6.79
1980	4.44	5.45	7.18	6.16	7.05	8.12	9.51	14.26	9.80	8.85	8.12	5.07	8.10
1981	4.95	1.92	2.77	6.80	8.88	7.34	9.02	7.27	7.29	5.88	3.51	2.52	5.72
1982	2.90	5.67	3.54	3.86	2.43	4.92	3.26	5.78	5.12	7.09	5.16	5.88	4.68
1983	4.06	5.37	3.89	4.74	6.63	5.61	6.53	6.23	8.45	6.55	5.63	4.50	5.79
1984	8.07	3.00	2.77	4.48	5.00	5.89	5.62	8.50	9.33	5.62	4.83	4.23	5.75
1985	1.94	4.77	4.03	4.61	4.43	10.64	8.74	10.23	11.10	13.18	6.87	7.54	7.53
1986	7.16	6.43	9.50	5.91	8.21	8.14	8.71	7.45	8.32	7.26	6.33	6.33	7.54
1987	4.34	0.25	5.56	5.63	7.24	7.88	8.13	11.33	4.89	8.99	7.06	7.92	6.74
1988	7.05	9.81	9.45	9.85	8.16	8.34	7.26	11.10	10.20	8.63	9.76	10.08	9.15
1989	7.99	0.00	0.00	0.00	6.68	7.52	10.58	10.74	11.78	10.48	8.74	10.40	7.43
1990	11.17	6.19	7.81	6.62	7.38	7.41	5.91	4.32	0.00	0.00	0.00	5.30	5.14
% TOTAL													
MONTHLY	10.05	9.10	9.10	9.41	9.60	9.87	10.42	10.85	9.90	10.69	9.50	9.29	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #4: 9.85 PERCENT

Table 6: Percentage of total monthly and yearly production provided by City of Rolla, well #4.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #5
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	4.17	4.24	5.04	4.36	7.29	2.58	2.93	6.58	4.51	4.36	3.66	49.72
1958	3.04	5.28	3.72	3.70	3.66	4.29	3.17	5.99	5.19	4.19	4.99	5.22	52.44
1959	4.47	5.23	4.45	5.09	4.98	6.41	6.13	6.86	5.65	6.01	5.18	5.20	65.65
1960	3.67	3.71	3.36	3.68	5.79	5.81	5.51	5.52	5.92	4.69	4.74	4.58	56.98
1961	4.39	4.74	4.82	3.91	4.25	4.75	5.12	4.35	5.91	5.11	5.08	3.96	56.40
1962	4.87	5.96	5.13	5.75	6.95	7.03	6.32	6.43	5.76	5.16	5.32	4.94	69.62
1963	5.62	6.32	5.24	5.14	5.18	5.25	5.23	4.80	6.13	5.64	5.46	5.90	65.91
1964	5.22	4.31	5.30	5.72	6.38	5.60	6.29	7.83	6.84	5.38	6.53	4.97	70.36
1965	5.05	5.24	5.14	5.21	5.74	5.43	9.93	5.30	4.58	4.28	3.21	1.10	60.21
1966	1.80	3.91	6.61	7.20	6.30	7.12	12.37	5.82	6.65	5.07	4.32	4.25	71.43
1967	5.13	6.27	3.64	4.68	4.26	4.58	5.74	7.68	7.31	7.20	3.49	4.56	64.54
1968	6.40	3.41	5.06	5.70	6.37	5.82	6.62	6.48	6.49	4.23	2.41	5.32	64.32
1969	4.63	7.58	3.95	4.96	5.24	5.03	5.54	5.17	5.80	4.11	0.00	0.00	52.01
1970	4.05	4.46	4.16	4.36	5.61	4.93	5.96	5.65	5.26	6.19	5.58	6.11	62.33
1971	4.72	7.56	6.54	8.96	7.28	6.95	9.24	8.76	7.49	7.02	6.79	6.17	87.47
1972	4.84	8.25	7.18	5.95	6.39	7.13	8.09	9.26	8.05	7.55	4.93	5.93	83.55
1973	5.80	5.37	3.39	5.01	6.99	7.48	6.77	7.95	6.25	6.01	6.77	5.70	73.49
1974	6.13	4.70	4.95	6.48	4.58	5.33	7.66	7.02	4.13	5.24	6.38	4.80	67.40
1975	5.13	5.33	5.62	5.37	5.09	7.01	4.62	6.95	6.46	5.37	6.26	5.24	68.46
1976	5.79	6.14	6.34	5.94	4.87	5.51	7.25	6.27	6.67	7.68	5.40	5.81	73.67
1977	5.89	6.97	5.95	5.07	4.82	6.99	5.98	9.67	8.12	6.61	8.49	6.81	81.38
1978	4.15	6.18	5.24	5.52	6.30	6.97	7.46	5.84	6.34	5.83	6.38	5.24	71.46
1979	5.99	5.48	5.69	4.84	5.78	5.20	5.64	6.10	8.52	6.54	5.79	5.55	71.13
1980	0.76	0.00	0.00	5.19	11.21	11.21	15.46	11.37	8.55	8.03	6.07	6.34	84.19
1981	5.82	6.28	5.87	6.47	6.18	6.43	9.31	9.97	9.62	7.49	8.97	5.60	88.03
1982	5.25	8.72	4.63	4.87	6.72	3.98	4.82	7.14	7.25	5.99	6.99	6.52	72.89
1983	6.47	5.25	5.35	6.34	6.62	7.78	6.26	8.31	5.69	5.42	5.15	5.00	73.64
1984	5.05	4.51	5.57	5.97	5.03	6.59	6.88	5.84	7.62	6.03	5.41	4.85	69.37
1985	5.87	4.29	5.12	5.55	5.09	5.21	7.89	7.32	8.70	3.90	7.92	5.89	72.73
1986	6.03	5.94	5.43	4.76	5.22	5.08	2.50	5.67	6.47	8.04	5.93	8.07	69.15
1987	5.72	5.20	6.86	5.90	5.95	8.55	7.26	9.00	9.24	8.73	7.21	5.60	85.21
1988	5.93	6.70	7.21	6.21	7.14	8.25	6.60	9.30	6.78	6.57	6.42	5.85	82.96
1989	6.58	5.86	6.45	6.57	8.38	6.32	7.45	7.43	7.35	7.00	5.32	6.00	80.72
1990	6.34	5.91	4.79	3.26	6.12	4.21	6.14	7.03	5.55	0.68	0.00	0.00	50.02
TOTAL													
MONTHLY PRODUCTION	166.59	185.25	173.00	184.39	200.83	211.56	229.81	237.00	228.93	197.49	183.23	170.75	

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #5: 2368.841 MILLION GALLONS

Table 7: Monthly and yearly production, City of Rolla, well #5, 1957-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	20.94	23.49	23.61	21.00	29.19	9.83	10.48	25.17	20.19	20.26	17.96	19.92
1958	15.53	23.73	18.84	17.35	17.71	18.77	14.27	25.15	20.63	17.30	21.73	24.14	19.68
1959	21.26	23.18	21.51	22.01	20.27	22.12	20.56	21.90	20.98	23.51	20.71	23.26	21.74
1960	16.93	16.81	15.97	15.52	24.68	22.48	19.53	21.68	21.90	18.31	19.56	20.89	19.63
1961	19.59	19.95	25.52	16.74	18.18	24.72	21.13	16.16	22.22	19.56	20.71	18.43	20.08
1962	20.81	23.32	22.71	21.45	23.48	25.52	20.50	19.61	19.81	19.78	21.38	20.56	21.54
1963	23.76	23.66	22.68	19.43	19.61	18.96	18.02	17.12	21.50	17.13	19.84	24.70	20.35
1964	20.71	17.13	21.96	21.50	22.94	20.04	19.58	21.71	20.59	17.63	21.37	19.43	20.40
1965	19.38	19.36	20.82	19.38	16.78	18.53	28.98	16.04	15.84	13.53	10.06	3.83	16.88
1966	6.28	12.57	22.64	22.16	19.76	20.58	23.29	15.37	18.61	12.74	12.31	13.46	16.96
1967	16.23	18.98	11.82	13.45	12.95	13.86	14.84	16.83	15.27	17.03	8.56	12.12	14.37
1968	16.39	8.42	12.91	13.77	14.46	13.57	12.86	13.92	12.83	8.94	5.22	13.53	12.17
1969	11.97	18.30	10.00	11.38	11.52	11.14	11.21	10.37	12.74	8.97	0.00	0.00	9.74
1970	9.68	9.67	9.63	9.43	11.51	10.22	10.41	9.97	9.02	12.33	11.41	13.29	10.53
1971	11.18	15.12	14.92	17.78	14.15	13.62	14.35	14.84	12.14	13.82	13.78	13.82	14.14
1972	13.21	17.96	15.31	13.12	13.49	12.59	13.62	16.37	14.98	14.95	9.90	12.91	14.05
1973	11.85	11.85	7.11	11.09	15.19	15.81	11.91	13.74	11.02	12.44	13.40	13.49	12.39
1974	13.69	11.80	11.67	15.15	10.73	12.26	12.63	11.81	8.03	11.77	13.72	11.63	12.04
1975	10.83	10.68	10.77	11.89	10.18	12.59	6.91	10.80	10.15	8.88	10.94	9.43	10.24
1976	10.70	11.42	11.17	11.13	8.94	9.56	11.35	9.61	9.11	11.54	8.56	9.89	10.22
1977	9.13	10.58	9.94	8.68	7.74	10.93	10.51	15.34	13.20	11.78	14.11	13.04	11.23
1978	8.17	12.10	10.39	9.70	12.02	12.50	11.38	10.22	9.13	9.68	10.78	9.53	10.45
1979	10.71	10.05	9.29	8.89	8.95	9.20	9.06	9.34	13.09	9.76	9.79	8.80	9.75
1980	1.34	0.00	0.00	9.28	20.49	18.90	18.91	15.40	12.91	11.88	10.20	11.42	11.35
1981	10.05	11.33	9.43	11.92	9.65	10.43	15.03	17.42	14.05	11.74	14.94	8.81	12.05
1982	9.15	12.80	7.83	8.36	10.34	6.30	7.90	9.63	9.14	9.41	10.28	11.40	9.41
1983	11.45	9.33	8.89	11.83	10.76	12.95	8.41	8.83	8.00	8.49	8.78	8.54	9.58
1984	8.29	8.23	9.40	10.41	8.42	11.11	10.45	7.86	11.48	10.26	9.78	9.19	9.57
1985	10.44	8.02	9.16	9.39	8.75	10.08	10.48	11.58	12.12	5.94	14.13	10.51	10.07
1986	11.15	11.71	9.43	8.42	9.15	8.37	3.59	8.57	9.27	12.98	11.20	14.17	9.68
1987	11.24	9.60	11.24	9.99	11.01	12.70	11.16	12.76	13.69	14.39	12.29	10.33	11.79
1988	11.34	11.49	12.74	11.13	10.11	10.57	11.59	13.14	10.84	10.94	11.96	11.33	11.41
1989	11.68	11.70	11.59	12.22	12.53	10.84	10.60	10.55	11.66	9.94	8.78	10.00	10.97
1990	10.02	11.42	7.62	5.77	10.50	6.77	9.71	10.42	7.95	1.07	0.00	0.00	6.86
% TOTAL													
MONTHLY PRODUCTION	11.65	12.60	11.66	12.37	12.75	13.15	12.70	12.94	12.70	11.80	11.57	11.47	

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #5: 12.31 PERCENT

Table 8: Percentage of total monthly and yearly production provided by City of Rolla, well #5.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #6
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	4.73	4.55	5.49	5.08	5.53	4.58	4.84	4.62	4.36	4.50	4.33	52.61
1958	4.49	4.99	4.56	4.17	4.16	5.70	4.10	5.78	7.22	6.82	4.90	5.48	62.38
1959	5.05	4.82	5.05	5.50	5.98	7.59	7.97	8.97	7.19	7.48	7.14	5.72	79.46
1960	4.08	4.87	4.09	4.26	4.22	6.86	5.29	4.95	4.73	3.86	3.90	3.63	54.75
1961	3.61	3.78	3.38	3.27	3.60	3.06	4.03	3.76	3.03	3.73	3.74	3.27	42.26
1962	3.59	3.60	1.88	3.08	0.00	2.65	4.82	6.69	5.34	4.78	4.21	4.22	44.88
1963	3.97	4.46	3.57	4.27	4.08	5.02	4.84	6.30	4.31	5.40	5.40	4.17	55.80
1964	4.44	4.43	5.17	5.52	3.81	5.59	5.25	6.92	6.88	6.28	6.01	5.02	65.32
1965	4.39	5.27	3.98	5.65	7.06	5.11	6.88	7.59	4.75	6.04	5.47	7.52	69.72
1966	6.84	6.65	5.39	6.78	5.30	6.60	8.99	5.00	5.66	6.26	4.05	5.00	72.52
1967	4.36	5.25	3.91	4.96	4.38	4.97	3.28	6.82	6.49	5.25	5.03	3.49	58.18
1968	4.72	5.29	4.99	4.71	4.42	5.45	4.69	5.37	5.83	6.97	6.75	4.59	63.79
1969	4.48	3.67	5.13	6.15	4.92	5.34	7.74	6.38	5.64	5.43	0.00	0.00	54.88
1970	6.84	6.91	6.89	6.66	6.67	5.21	4.30	4.53	5.32	3.23	5.26	4.14	65.96
1971	3.65	4.62	4.06	4.18	3.94	4.17	3.82	4.70	4.30	3.89	4.16	3.22	48.71
1972	3.05	3.33	3.51	3.61	3.67	4.62	3.78	3.57	4.18	3.67	3.10	2.57	42.67
1973	1.36	3.19	4.30	2.99	3.42	3.91	4.24	3.28	4.02	3.41	2.89	2.53	39.54
1974	0.00	1.70	3.24	2.19	1.91	1.72	4.24	4.90	2.77	1.33	2.01	1.42	27.43
1975	5.63	2.74	2.98	2.47	2.15	2.76	4.92	3.51	3.93	2.95	4.46	3.39	41.89
1976	2.10	2.74	1.85	1.83	2.49	2.46	3.25	3.58	4.23	4.44	4.20	3.94	37.10
1977	5.83	4.04	4.62	3.61	3.12	3.92	1.96	5.10	4.01	3.49	4.09	1.72	45.49
1978	1.47	2.43	2.40	3.29	4.26	4.53	5.43	6.52	9.26	4.12	2.63	2.45	48.77
1979	2.66	2.79	2.68	2.29	2.10	2.09	3.44	3.70	2.86	3.83	2.30	2.85	33.57
1980	1.67	2.51	1.96	2.55	3.00	3.10	5.66	6.62	5.58	5.22	4.06	3.60	45.53
1981	1.54	2.50	3.51	0.00	0.17	0.00	0.00	4.62	4.46	3.46	4.05	4.16	28.46
1982	1.95	3.55	1.63	1.07	2.16	3.27	3.59	7.14	4.70	2.89	4.47	2.79	39.20
1983	1.97	3.65	3.21	4.32	3.17	4.61	5.79	7.45	6.55	4.08	3.62	2.60	51.02
1984	3.31	2.70	4.10	2.93	3.45	4.26	4.39	6.98	6.24	4.23	4.12	2.96	49.68
1985	2.71	2.34	3.25	2.34	3.25	4.83	7.79	4.17	6.57	7.72	6.43	4.81	56.20
1986	6.04	3.99	5.29	4.94	6.76	4.48	7.43	5.16	6.22	5.59	5.13	5.71	66.74
1987	4.08	4.53	4.02	3.86	4.81	5.64	6.82	6.42	5.41	3.74	4.56	4.96	58.85
1988	4.41	6.02	2.35	5.00	5.78	7.90	5.15	7.41	5.31	4.07	3.62	3.23	60.26
1989	4.56	3.70	4.41	4.55	7.45	5.88	6.86	6.85	5.57	5.92	4.85	5.39	65.98
1990	4.36	3.47	3.50	4.00	3.38	4.72	4.55	5.45	4.59	5.80	4.09	4.38	52.30
TOTAL													
MONTHLY PRODUCTION	123.20	135.28	129.40	132.51	134.12	153.55	169.86	191.02	177.77	159.74	145.20	129.27	

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #6: 1780.92 MILLION GALLONS

Table 9: Monthly and yearly production, City of Rolla, well #6, 1957-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #6

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	23.77	25.24	25.72	24.47	22.12	17.46	17.28	17.65	19.50	20.92	21.26	21.07
1958	22.96	22.44	23.08	19.54	20.16	24.98	18.48	24.24	28.70	28.17	21.37	25.32	23.42
1959	23.98	21.36	24.40	23.76	24.37	26.16	26.76	28.65	26.70	29.25	28.57	25.62	25.99
1960	18.86	22.05	19.46	17.97	18.00	26.53	18.75	19.46	17.50	15.06	16.09	16.57	18.86
1961	16.12	15.93	17.91	13.97	15.40	15.92	16.61	13.98	11.40	14.28	15.25	15.22	15.04
1962	15.32	14.11	8.34	11.50	0.00	9.63	15.63	20.41	18.35	18.33	16.93	17.57	13.89
1963	16.78	16.69	15.46	16.11	15.46	18.15	16.68	22.46	15.11	16.42	19.66	17.46	17.23
1964	17.61	17.63	21.41	20.77	13.71	20.00	16.32	19.18	20.73	20.57	19.68	19.62	18.94
1965	16.85	19.48	16.11	21.05	20.66	17.42	20.07	22.96	16.44	19.10	17.16	26.14	19.55
1966	23.84	21.40	18.45	20.87	16.61	19.08	16.93	13.21	15.83	15.72	11.56	15.83	17.22
1967	13.79	15.88	12.69	14.28	13.31	15.07	8.48	14.96	13.55	12.42	12.32	9.26	12.96
1968	12.10	13.06	12.75	11.98	10.03	12.70	9.10	11.54	11.53	14.72	14.61	11.69	12.07
1969	11.58	8.86	12.98	14.12	10.82	11.83	15.66	12.80	12.37	11.86	0.00	0.00	10.27
1970	16.33	15.00	15.96	14.40	13.68	10.79	7.51	7.99	9.14	6.43	10.75	9.01	11.15
1971	8.65	9.24	9.27	8.30	7.65	8.17	5.94	7.95	6.97	7.66	8.44	7.22	7.87
1972	8.32	7.24	7.48	7.96	7.75	8.16	6.36	6.32	7.79	7.28	6.23	5.60	7.17
1973	2.77	7.05	9.02	6.62	7.45	8.26	7.46	5.67	7.08	7.06	5.72	5.99	6.67
1974	0.00	4.27	7.62	5.12	4.48	3.96	6.99	8.24	5.39	3.00	4.31	3.44	4.90
1975	11.87	5.48	5.72	5.47	4.30	4.96	7.35	5.45	6.17	4.87	7.80	6.11	6.27
1976	3.88	5.10	3.25	3.43	4.56	4.27	5.08	5.50	5.77	6.67	6.65	6.71	5.15
1977	9.02	6.13	7.71	6.18	5.01	6.13	3.45	8.09	6.51	6.22	6.80	3.29	6.28
1978	2.90	4.76	4.75	5.78	8.12	8.12	8.28	11.41	13.33	6.84	4.44	4.45	7.13
1979	4.75	5.12	4.37	4.20	3.25	3.70	5.52	5.66	4.39	5.71	3.88	4.52	4.60
1980	2.96	4.64	3.44	4.57	5.48	5.23	6.92	8.97	8.43	7.73	6.82	6.48	6.14
1981	2.66	4.51	5.63	0.00	0.26	0.00	0.00	8.06	6.51	5.42	6.74	6.54	3.89
1982	3.40	5.21	2.75	1.83	3.32	5.17	5.88	9.63	5.92	4.55	6.57	4.88	5.06
1983	3.49	6.48	5.34	8.06	5.16	7.67	7.77	7.91	9.19	6.40	6.17	4.45	6.64
1984	5.43	4.92	6.92	5.11	5.77	7.17	6.67	9.39	9.40	7.21	7.45	5.61	6.85
1985	4.81	4.38	5.82	3.97	5.59	9.33	10.35	6.61	9.15	11.75	11.47	8.58	7.78
1986	11.17	7.86	9.19	8.74	11.84	7.38	10.64	7.81	8.91	9.02	9.70	10.04	9.34
1987	8.03	8.36	6.59	6.53	8.90	8.38	10.49	9.10	8.02	6.17	7.77	9.14	8.14
1988	8.45	10.33	4.16	8.96	8.18	10.12	9.04	10.46	8.50	6.78	6.74	6.26	8.28
1989	8.10	7.39	7.92	8.46	11.13	10.09	9.76	9.72	8.83	8.41	8.00	8.98	8.97
1990	6.90	6.71	5.57	7.08	5.80	7.59	7.19	8.08	6.57	9.24	7.49	7.71	7.17
% TOTAL													
MONTHLY	8.61	9.20	8.72	8.89	8.51	9.55	9.39	10.43	9.86	9.54	9.17	8.68	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #6: 9.25 PERCENT

Table 10: Percentage of total monthly and yearly production provided by City of Rolla, well #6.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #7
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	1.68	0.00	0.00	0.00	0.00	6.16	7.37	5.34	4.74	3.78	3.20	32.27
1958	2.71	0.00	2.46	3.79	3.77	3.69	5.49	0.00	0.00	0.00	0.00	0.00	21.91
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	3.47	3.40	4.10	5.58	4.24	4.74	4.19	3.99	3.97	4.18	4.64	3.93	50.43
1961	3.95	4.25	3.56	3.39	4.02	3.56	3.49	3.59	4.18	4.03	4.09	3.55	45.65
1962	3.50	4.15	4.46	5.01	5.18	4.74	4.39	4.72	4.17	3.32	3.89	3.92	51.44
1963	4.14	3.75	3.36	3.81	3.81	3.14	4.11	3.97	4.46	4.11	3.92	3.95	46.53
1964	4.17	3.89	1.84	2.77	4.71	3.17	4.93	4.16	5.12	5.02	5.20	4.29	49.26
1965	4.20	4.41	4.28	4.41	5.03	4.27	2.24	2.89	2.70	4.11	1.78	1.20	41.53
1966	1.65	3.21	4.68	4.50	3.66	3.18	5.32	2.37	3.45	4.59	4.41	2.54	43.57
1967	2.59	2.59	2.69	2.93	3.37	2.54	3.39	3.98	4.86	2.38	4.86	3.57	39.74
1968	3.37	3.35	2.54	4.44	3.41	3.11	4.73	4.22	4.20	3.14	2.79	2.58	41.88
1969	3.41	0.00	1.09	2.92	3.64	4.72	2.75	5.11	4.90	5.35	5.83	7.28	47.00
1970	4.55	5.55	4.36	4.94	4.55	5.96	7.88	8.91	8.33	7.81	6.45	5.24	74.55
1971	4.32	5.90	4.58	5.21	4.16	6.04	5.36	5.60	6.12	5.36	5.35	5.17	63.16
1972	3.89	2.38	4.21	5.11	5.75	6.49	5.79	5.35	5.53	4.61	5.62	3.59	58.34
1973	4.93	4.02	5.05	4.84	2.71	0.00	5.03	4.86	4.19	5.33	4.46	3.29	48.72
1974	3.88	3.25	4.27	3.81	4.24	4.39	4.75	5.47	5.09	4.52	4.64	4.22	52.52
1975	4.10	4.19	4.74	3.94	2.83	1.21	4.81	4.75	4.81	4.44	4.35	5.23	49.40
1976	4.05	3.91	4.05	4.21	5.33	4.49	4.18	5.58	6.24	4.30	5.18	4.46	55.98
1977	4.45	4.87	4.31	5.05	5.39	4.93	4.49	6.26	8.29	8.45	8.17	3.40	68.06
1978	4.42	4.10	4.81	4.69	4.15	4.38	5.09	3.98	5.13	3.38	3.96	4.05	52.14
1979	4.05	4.75	4.64	4.42	4.31	4.11	4.34	4.92	3.46	4.03	4.50	4.48	51.99
1980	4.70	4.07	5.29	0.66	0.00	0.00	0.00	4.29	5.12	2.60	5.57	5.04	37.34
1981	4.58	4.47	5.58	4.44	4.73	4.75	3.21	1.23	0.00	0.00	1.29	5.01	39.30
1982	5.09	5.47	3.72	4.13	3.99	3.68	4.11	4.69	6.52	6.21	2.95	4.01	54.56
1983	2.06	3.54	4.47	3.64	5.12	4.77	6.85	3.02	0.00	3.50	2.64	3.92	43.52
1984	2.59	3.33	1.16	0.00	1.76	1.45	2.89	3.81	3.00	2.36	3.11	2.53	27.99
1985	3.10	3.21	3.12	2.78	3.68	2.99	5.20	4.12	4.46	2.56	2.79	3.96	41.98
1986	4.23	2.78	4.29	3.36	3.77	3.40	4.34	5.20	5.45	4.05	3.55	3.37	47.78
1987	2.03	3.81	3.27	3.32	4.03	3.50	4.45	2.70	5.31	2.96	3.22	3.85	42.45
1988	3.34	1.80	2.21	1.66	3.84	6.35	5.50	5.63	5.70	4.68	3.99	4.56	49.28
1989	4.60	4.00	4.69	3.92	4.99	1.41	5.04	5.04	5.15	5.04	4.18	4.06	52.12
1990	4.43	3.31	1.55	2.90	2.03	2.80	1.79	3.31	2.73	3.18	2.54	4.03	34.59
TOTAL													
MONTHLY PRODUCTION	120.53	117.38	119.43	120.60	126.21	117.95	146.31	145.10	147.97	134.32	133.67	127.49	

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #7: 1556.961 MILLION GALLONS

Table 11: Monthly and yearly production, City of Rolla, well #7, 1957-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #7

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	8.44	0.00	0.00	0.00	0.00	23.48	26.34	20.42	21.18	17.58	15.72	12.93
1958	13.85	0.00	12.44	17.75	18.28	16.17	24.70	0.00	0.00	0.00	0.00	0.00	8.22
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	16.04	15.39	19.51	23.50	18.08	18.32	14.87	15.68	14.69	16.32	19.16	17.94	17.38
1961	17.63	17.91	18.83	14.50	17.16	18.50	14.38	13.36	15.71	15.43	16.68	16.52	16.25
1962	14.93	16.24	19.73	18.70	17.50	17.21	14.22	14.40	14.34	12.73	15.64	16.30	15.92
1963	17.47	14.01	14.55	14.40	14.44	11.36	14.17	14.16	15.66	12.49	14.25	16.51	14.36
1964	16.55	15.46	7.61	10.41	16.95	11.35	15.34	11.53	15.41	16.44	17.03	16.76	14.28
1965	16.13	16.28	17.36	16.43	14.72	14.57	6.53	8.73	9.33	12.99	5.58	4.18	11.64
1966	5.75	10.33	16.01	13.85	11.48	9.19	10.02	6.26	9.66	11.54	12.58	8.06	10.35
1967	8.20	7.83	8.75	8.42	10.23	7.68	8.77	8.73	10.14	5.62	11.90	9.49	8.85
1968	8.62	8.29	6.50	10.72	7.75	7.26	9.18	9.06	8.29	6.64	6.03	6.56	7.92
1969	8.81	0.00	2.76	6.70	8.00	10.45	5.56	10.27	10.77	11.67	12.40	17.03	8.80
1970	10.87	12.04	10.11	10.68	9.34	12.35	13.76	15.72	14.30	15.55	13.19	11.41	12.60
1971	10.24	11.81	10.45	10.34	8.08	11.84	8.32	9.48	9.92	10.55	10.84	11.58	10.21
1972	10.62	5.19	8.98	11.28	12.15	11.46	9.75	9.46	10.30	9.14	11.29	7.82	9.81
1973	10.07	8.88	10.61	10.71	5.90	0.00	8.85	8.40	7.39	11.04	8.83	7.77	8.22
1974	8.67	8.15	10.05	8.92	9.93	10.09	7.83	9.20	9.90	10.15	9.97	10.24	9.38
1975	8.65	8.40	9.09	8.72	5.66	2.17	7.18	7.39	7.55	7.33	7.61	9.40	7.39
1976	7.48	7.27	7.14	7.89	9.78	7.79	6.55	8.56	8.51	6.46	8.21	7.60	7.77
1977	6.88	7.40	7.20	8.65	8.66	7.71	7.89	9.93	13.48	15.08	13.57	6.51	9.39
1978	8.71	8.03	9.52	8.23	7.92	7.86	7.76	6.96	7.39	5.60	6.69	7.37	7.62
1979	7.24	8.70	7.57	8.12	6.67	7.26	6.97	7.52	5.31	6.02	7.60	7.10	7.13
1980	8.34	7.53	9.31	1.18	0.00	0.00	0.00	5.81	7.72	3.85	9.35	9.08	5.03
1981	7.91	8.07	8.95	8.18	7.38	7.70	5.19	2.15	0.00	0.00	2.14	7.88	5.38
1982	8.88	8.02	6.29	7.08	6.14	5.81	6.73	6.33	8.22	9.76	4.34	7.01	7.04
1983	3.64	6.30	7.42	6.80	8.33	7.94	9.21	3.21	0.00	5.48	4.50	6.69	5.66
1984	4.25	6.08	1.95	0.00	2.95	2.44	4.40	5.12	4.52	4.01	5.63	4.80	3.86
1985	5.51	6.00	5.60	4.70	6.34	5.79	6.91	6.52	6.21	3.90	4.98	7.07	5.81
1986	7.82	5.47	7.45	5.94	6.60	5.60	6.22	7.86	7.81	6.53	6.71	5.92	6.69
1987	3.99	7.02	5.36	5.63	7.45	5.20	6.84	3.84	7.87	4.88	5.50	7.10	5.87
1988	6.39	3.09	3.91	2.98	5.44	8.14	9.66	7.95	9.11	7.79	7.44	8.83	6.77
1989	8.17	7.98	8.43	7.30	7.45	2.41	7.17	7.15	8.17	7.16	6.88	6.77	7.08
1990	7.01	6.38	2.47	5.12	3.49	4.50	2.82	4.91	3.92	5.07	4.64	7.10	4.74
% TOTAL													
MONTHLY	8.43	7.98	8.05	8.09	8.01	7.33	8.09	7.92	8.21	8.02	8.44	8.56	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #7: 8.09 PERCENT

Table 12: Percentage of total monthly and yearly production provided by City of Rolla, well #7.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #8
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.54	1.69	0.39	4.63
1961	1.11	0.81	0.00	3.38	2.57	1.44	1.49	2.53	2.62	1.60	0.96	1.25	19.75
1962	0.55	1.68	0.64	2.74	3.31	1.55	1.91	1.28	1.14	1.72	1.81	1.27	19.60
1963	1.31	1.74	1.03	1.98	2.95	2.37	2.74	2.18	1.74	2.20	1.81	1.53	23.57
1964	1.65	1.57	0.77	1.13	1.44	1.34	1.67	1.65	1.06	0.78	1.37	0.33	14.76
1965	1.05	1.04	0.91	1.42	1.85	0.75	1.92	2.24	3.05	2.77	3.60	3.13	23.71
1966	2.09	1.36	1.72	1.63	1.26	1.76	1.59	1.11	1.30	1.54	1.36	0.62	17.34
1967	0.95	1.27	1.07	0.95	0.65	1.56	0.76	1.20	0.95	1.21	1.09	0.65	12.32
1968	0.93	0.61	0.83	0.32	0.87	0.60	1.10	0.99	1.03	1.30	0.75	1.26	10.60
1969	0.32	1.23	1.31	1.72	1.60	0.93	2.61	2.56	2.92	2.40	3.89	2.96	24.45
1970	1.57	1.19	2.79	2.58	3.15	2.76	2.46	2.09	2.84	2.06	2.91	2.45	28.86
1971	2.54	2.61	2.55	2.51	2.53	2.31	2.58	0.00	3.42	2.48	2.91	2.47	28.91
1972	2.03	2.46	2.43	2.45	0.00	2.08	2.72	2.54	2.43	2.19	2.42	2.17	25.93
1973	2.31	2.18	1.90	1.29	1.50	1.34	1.52	2.14	2.42	2.03	1.74	2.12	22.49
1974	2.53	1.96	1.84	1.68	1.85	1.86	1.82	1.27	2.67	0.98	1.25	1.60	21.32
1975	2.20	0.95	0.00	0.00	0.00	2.40	1.93	2.39	2.68	1.98	0.00	0.73	15.25
1976	1.77	1.75	2.04	2.40	1.96	2.81	2.49	2.88	3.09	2.58	2.30	2.65	28.73
1977	2.29	2.36	2.43	3.35	1.89	1.93	2.67	2.58	2.35	2.57	2.30	1.94	28.66
1978	2.26	1.84	2.18	2.68	2.27	2.32	2.66	2.39	2.67	2.37	2.78	2.43	28.86
1979	2.35	2.48	2.41	2.16	2.25	2.44	2.53	2.24	2.06	2.68	2.73	3.38	29.70
1980	5.47	5.53	5.00	3.92	2.27	2.28	2.71	3.40	2.41	2.56	2.34	2.72	40.62
1981	3.23	2.02	2.87	2.13	2.41	2.70	2.78	3.27	3.14	2.73	2.75	3.02	33.06
1982	2.30	3.12	2.03	2.14	1.83	2.53	2.67	2.75	3.06	2.72	2.96	2.42	30.51
1983	2.67	2.55	2.78	2.58	3.79	2.83	2.76	4.18	2.96	2.87	2.40	2.33	34.71
1984	2.16	2.45	2.67	3.24	2.81	3.33	3.24	2.71	2.88	2.18	2.42	2.25	32.34
1985	2.40	2.20	2.27	2.53	2.36	2.07	2.61	1.98	2.62	3.13	2.08	1.66	27.91
1986	1.94	2.20	1.56	1.32	1.34	1.75	2.67	1.74	1.66	1.71	1.04	1.82	20.75
1987	0.33	1.86	0.95	1.49	1.36	0.00	0.00	0.00	0.31	2.74	2.08	2.36	13.49
1988	1.34	2.87	2.49	3.92	3.76	3.43	2.23	3.78	2.94	2.71	2.72	2.43	34.61
1989	2.65	2.52	2.89	2.42	3.32	2.61	2.56	3.42	2.48	3.29	1.97	2.36	32.49
1990	2.40	1.53	1.50	1.74	1.85	1.97	0.98	1.46	3.25	2.60	1.73	2.13	23.11
TOTAL													
MONTHLY	58.69	59.95	55.85	63.82	61.04	60.04	64.36	64.93	70.15	69.20	64.16	60.82	
PRODUCTION													

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #8: 753.0161 MILLION GALLONS

Table 13: Monthly and yearly production, City of Rolla, well #8, 1960-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #8

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.93	6.98	1.79	1.59
1961	4.94	3.40	0.00	14.45	10.99	7.47	6.14	9.39	9.86	6.13	3.91	5.82	7.03
1962	2.36	6.56	2.82	10.22	11.20	5.64	6.21	3.91	3.92	6.57	7.27	5.30	6.07
1963	5.52	6.52	4.45	7.48	11.19	8.55	9.43	7.78	6.09	6.67	6.60	6.38	7.28
1964	6.56	6.23	3.20	4.26	5.17	4.79	5.19	4.56	3.19	2.56	4.49	1.30	4.28
1965	4.02	3.84	3.70	5.27	5.40	2.55	5.59	6.76	10.54	8.74	11.29	10.87	6.65
1966	7.29	4.38	5.89	5.02	3.94	5.08	2.99	2.93	3.63	3.87	3.87	1.97	4.12
1967	3.00	3.85	3.48	2.74	1.99	4.74	1.96	2.62	1.99	2.86	2.66	1.74	2.74
1968	2.37	1.51	2.12	0.77	1.98	1.41	2.14	2.13	2.03	2.76	1.62	3.20	2.01
1969	0.84	2.97	3.31	3.95	3.52	2.07	5.28	5.13	6.41	5.23	8.27	6.92	4.58
1970	3.74	2.58	6.46	5.58	6.47	5.71	4.30	3.69	4.88	4.11	5.95	5.34	4.88
1971	6.03	5.21	5.81	4.99	4.92	4.52	4.00	0.00	5.55	4.88	5.91	5.54	4.67
1972	5.55	5.35	5.19	5.40	0.00	3.68	4.58	4.49	4.53	4.34	4.87	4.72	4.36
1973	4.71	4.82	3.98	2.86	3.27	2.83	2.67	3.70	4.27	4.20	3.44	5.02	3.79
1974	5.66	4.91	4.34	3.94	4.33	4.28	3.00	2.14	5.20	2.21	2.69	3.88	3.81
1975	4.64	1.90	0.00	0.00	0.00	4.31	2.88	3.71	4.21	3.27	0.00	1.31	2.28
1976	3.28	3.26	3.59	4.49	3.59	4.88	3.90	4.42	4.22	3.88	3.65	4.51	3.99
1977	3.55	3.58	4.06	5.74	3.04	3.01	4.70	4.10	3.81	4.59	3.82	3.70	3.95
1978	4.45	3.61	4.31	4.71	4.34	4.16	4.07	4.18	3.85	3.94	4.69	4.43	4.22
1979	4.20	4.55	3.93	3.96	3.49	4.31	4.06	3.43	3.17	3.99	4.61	5.36	4.07
1980	9.69	10.24	8.80	7.00	4.16	3.84	3.32	4.61	3.64	3.80	3.93	4.90	5.48
1981	5.59	3.65	4.61	3.93	3.77	4.39	4.48	5.71	4.59	4.27	4.58	4.74	4.52
1982	4.00	4.57	3.43	3.67	2.82	3.99	4.37	3.71	3.86	4.27	4.35	4.22	3.94
1983	4.73	4.54	4.61	4.81	6.17	4.72	3.71	4.43	4.16	4.49	4.10	3.99	4.51
1984	3.54	4.47	4.50	5.65	4.71	5.62	4.92	3.64	4.34	3.71	4.38	4.27	4.46
1985	4.27	4.12	4.07	4.28	4.07	4.00	3.46	3.13	3.64	4.76	3.72	2.96	3.86
1986	3.59	4.34	2.71	2.34	2.35	2.88	3.83	2.64	2.37	2.76	1.96	3.19	2.90
1987	0.65	3.44	1.55	2.53	2.52	0.00	0.00	0.00	0.46	4.52	3.55	4.35	1.87
1988	2.56	4.92	4.40	7.02	5.32	4.40	3.91	5.34	4.70	4.51	5.06	4.70	4.76
1989	4.71	5.02	5.20	4.51	4.96	4.47	3.65	4.85	3.94	4.68	3.25	3.93	4.42
1990	3.79	2.96	2.38	3.07	3.16	3.16	1.54	2.16	4.66	4.13	3.16	3.75	3.17
%													
TOTAL													
MONTHLY	4.10	4.08	3.77	4.28	3.87	3.73	3.56	3.54	3.89	4.13	4.05	4.08	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #8: 3.91 PERCENT

Table 14: Percentage of total monthly and yearly production provided by City of Rolla, well #8.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #9
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	5.33	5.24	0.94	5.24	17.41
1967	5.92	5.90	7.40	6.49	7.11	6.11	7.43	9.00	6.54	8.78	8.40	7.36	86.42
1968	6.11	8.56	6.73	7.13	7.99	7.07	8.84	8.59	7.40	6.59	8.59	5.33	88.92
1969	5.35	6.92	6.76	6.46	6.62	5.25	5.77	5.35	4.36	5.24	11.74	7.65	77.46
1970	4.01	4.23	4.09	4.48	6.26	4.53	5.43	4.49	4.79	3.97	5.33	5.72	57.33
1971	5.80	5.88	5.53	5.23	8.83	6.94	9.25	9.04	9.28	7.47	6.19	5.63	85.07
1972	4.83	8.59	6.64	5.33	6.89	7.88	8.94	7.93	7.91	7.73	6.43	4.20	83.29
1973	5.09	5.29	8.77	6.68	7.70	10.83	6.81	9.18	8.89	5.26	7.88	7.02	89.40
1974	6.60	5.74	6.19	5.73	6.75	6.49	8.36	8.28	9.19	6.40	6.18	6.34	82.26
1975	4.28	4.08	7.37	4.62	7.88	7.40	9.88	7.29	6.68	7.71	6.72	4.86	78.75
1976	6.06	6.98	6.91	6.33	5.78	7.31	8.08	7.85	8.48	7.41	7.50	6.21	84.89
1977	7.21	6.46	6.65	6.25	7.51	7.32	6.75	3.61	0.00	0.00	0.89	7.11	59.76
1978	6.31	6.59	6.05	6.13	5.55	6.12	9.63	8.00	9.13	7.04	6.37	6.26	83.19
1979	6.06	6.02	6.00	4.86	6.42	5.68	6.11	7.27	7.52	9.40	6.82	7.41	79.56
1980	5.24	7.24	8.44	10.86	8.36	10.27	15.94	11.56	8.36	12.97	7.04	6.60	112.89
1981	5.60	5.25	6.50	6.16	7.39	6.32	5.82	6.68	14.17	11.98	8.82	7.09	91.79
1982	4.98	4.07	6.23	5.35	7.19	6.04	5.77	6.92	6.49	8.07	6.95	5.27	73.34
1983	6.57	5.70	6.46	5.64	7.05	4.55	8.50	9.64	8.57	7.83	6.48	5.41	82.40
1984	6.00	5.11	4.70	4.19	5.09	4.51	6.08	5.45	5.14	5.04	5.13	5.26	61.71
1985	3.98	3.35	4.18	5.53	4.79	6.13	6.77	6.15	6.40	6.85	5.79	5.62	65.53
1986	5.18	5.48	5.14	4.78	5.16	5.38	6.17	5.40	6.94	5.26	5.19	4.52	64.59
1987	4.63	4.00	5.98	5.65	5.22	5.24	4.88	5.09	0.00	0.00	0.00	0.00	40.69
1988	0.00	4.33	5.76	5.02	5.95	0.38	0.00	2.13	7.93	6.66	5.23	5.77	49.17
1989	6.66	5.68	5.48	6.13	8.76	5.22	6.97	8.04	7.25	7.01	3.32	2.98	73.50
1990	5.26	2.84	4.15	2.82	2.94	3.40	4.48	4.70	5.97	2.57	3.20	3.02	45.34
TOTAL													
MONTHLY PRODUCTION	127.71	134.32	148.10	137.84	159.18	146.38	172.65	168.32	172.73	162.47	147.14	137.86	

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #9: 1814.692 MILLION GALLONS

Table 15: Monthly and yearly production, City of Rolla, well #9, 1966-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #9

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.71	14.92	13.17	2.68	16.62	4.13
1967	18.71	17.84	24.04	18.66	21.61	18.51	19.22	19.73	13.66	20.76	20.59	19.54	19.25
1968	15.63	21.14	17.19	17.22	18.14	16.49	17.16	18.45	14.62	13.92	18.59	13.55	16.82
1969	13.83	16.69	17.11	14.83	14.55	11.63	11.67	10.74	9.57	11.43	24.94	17.90	14.50
1970	9.56	9.18	9.48	9.68	12.85	9.39	9.47	7.93	8.22	7.91	10.91	12.44	9.69
1971	13.76	11.77	12.60	10.39	17.16	13.61	14.37	15.30	15.05	14.71	12.56	12.60	13.75
1972	13.20	18.68	14.16	11.75	14.55	13.91	15.06	14.02	14.74	15.31	12.91	9.14	14.01
1973	10.40	11.69	18.42	14.77	16.75	22.88	11.98	15.86	15.68	10.90	15.60	16.59	15.08
1974	14.75	14.42	14.59	13.40	15.81	14.94	13.78	13.94	17.87	14.38	13.27	15.36	14.70
1975	9.03	8.16	14.13	10.23	15.74	13.29	14.76	11.32	10.49	12.74	11.75	8.75	11.78
1976	11.20	12.99	12.16	11.86	10.60	12.68	12.66	12.04	11.57	11.13	11.89	10.57	11.78
1977	11.16	9.81	11.12	10.70	12.06	11.44	11.87	5.74	0.00	0.00	1.48	13.60	8.25
1978	12.44	12.90	12.00	10.76	10.59	10.98	14.69	14.01	13.15	11.68	10.77	11.39	12.16
1979	10.83	11.05	9.79	8.91	9.94	10.04	9.81	11.13	11.55	14.02	11.52	11.76	10.91
1980	9.30	13.41	14.85	19.42	15.29	17.31	19.50	15.66	12.62	19.21	11.82	11.88	15.22
1981	9.67	9.48	10.43	11.34	11.52	10.26	9.39	11.67	20.69	18.76	14.70	11.15	12.56
1982	8.69	5.98	10.53	9.17	11.06	9.56	9.45	9.34	8.18	12.70	10.22	9.21	9.47
1983	11.62	10.12	10.73	10.52	11.48	7.57	11.43	10.23	12.04	12.27	11.04	9.25	10.72
1984	9.84	9.33	7.93	7.29	8.53	7.60	9.24	7.33	7.74	8.59	9.27	9.96	8.51
1985	7.07	6.27	7.49	9.36	8.24	11.85	8.99	9.73	8.92	10.43	10.33	10.03	9.07
1986	9.58	10.82	8.93	8.45	9.03	8.85	8.84	8.17	9.94	8.48	9.81	7.93	9.04
1987	9.10	7.38	9.80	9.58	9.67	7.78	7.50	7.22	0.00	0.00	0.00	0.00	5.63
1988	0.00	7.43	10.17	9.00	8.43	0.49	0.00	3.01	12.68	11.07	9.75	11.17	6.76
1989	11.83	11.34	9.85	11.42	13.09	8.95	9.92	11.41	11.50	9.95	5.48	4.96	9.99
1990	8.32	5.48	6.60	4.98	5.04	5.47	7.09	6.97	8.56	4.09	5.86	5.33	6.22
% TOTAL													
MONTHLY	8.93	9.13	9.98	9.25	10.11	9.10	9.54	9.19	9.58	9.70	9.29	9.26	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #9: 9.43 PERCENT

Table 16: Percentage of total monthly and yearly production provided by City of Rolla, well #9.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, UMR #2 WELL
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	2.78	6.77	6.35	6.55	5.98	5.13	4.91	38.47
1971	4.08	4.78	4.63	4.70	5.13	4.45	8.16	5.04	6.45	4.99	5.34	5.14	62.90
1972	3.82	4.06	4.81	5.28	4.59	5.63	6.10	6.59	5.10	5.37	4.99	2.84	59.17
1973	3.54	3.08	3.75	3.75	3.26	2.76	5.65	4.27	5.37	3.40	4.17	3.04	46.05
1974	3.54	3.20	3.37	3.01	3.71	3.55	3.88	5.23	4.23	3.88	4.01	3.78	45.37
1975	2.97	4.35	4.74	3.02	5.06	5.29	5.04	4.59	4.43	4.59	4.23	3.95	52.26
1976	4.28	4.18	4.72	3.95	3.91	4.19	3.70	3.74	4.38	3.72	3.73	3.54	48.05
1977	4.24	3.93	3.82	4.10	3.90	4.06	3.91	3.34	4.37	4.41	4.36	4.16	48.60
1978	3.74	3.98	3.67	4.45	3.67	4.27	4.83	5.85	8.24	5.28	3.96	4.12	56.06
1979	4.72	4.33	4.18	3.31	4.96	3.96	4.04	4.20	4.67	3.77	3.97	4.07	50.19
1980	4.43	4.13	4.16	3.82	4.02	4.00	6.15	5.12	4.96	5.07	5.11	4.36	55.34
1981	3.73	3.62	4.34	2.74	3.68	4.80	4.08	3.87	4.94	4.63	3.42	5.02	48.88
1982	2.64	0.00	3.35	2.57	3.54	3.88	3.44	3.74	3.10	3.73	4.98	2.56	37.52
1983	3.80	3.48	4.95	5.23	5.11	3.94	5.47	7.01	6.21	4.94	5.44	4.89	60.47
1984	4.63	4.54	3.72	3.44	4.88	4.39	3.65	5.76	3.29	5.52	4.39	4.23	52.45
1985	5.10	4.30	4.31	4.83	4.52	5.28	5.87	4.78	4.60	6.65	4.63	4.59	59.46
1986	4.15	5.25	5.02	4.90	5.21	7.20	7.10	4.70	4.91	3.62	3.54	0.64	56.22
1987	2.31	3.04	3.19	2.13	3.80	3.54	4.04	5.45	3.60	5.78	5.90	4.97	47.67
1988	4.64	3.99	2.91	3.48	3.32	3.95	0.47	1.80	0.14	0.00	0.00	0.00	24.71
1989	0.00	0.00	0.00	0.00	0.00	4.96	4.94	5.16	6.01	6.15	5.24	4.49	36.94
1990	6.60	4.34	4.97	3.35	4.14	4.72	2.83	0.00	0.00	0.00	0.00	0.00	30.95
TOTAL													
MONTHLY PRODUCTION	76.97	72.59	78.61	72.06	80.40	91.60	100.10	96.60	95.54	91.49	86.54	75.21	

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, UMR #2 WELL: 1017.72 MILLION GALLONS

Table 17: Monthly and yearly production, UMR well #2, 1970-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, UMR #2 WELL

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	5.76	11.83	11.21	11.24	11.91	10.49	10.68	6.50
1971	9.68	9.57	10.56	9.33	9.96	8.73	12.68	8.54	10.45	9.83	10.83	11.52	10.17
1972	10.43	8.83	10.25	11.64	9.69	9.94	10.28	11.65	9.49	10.63	10.02	6.19	9.95
1973	7.24	6.80	7.88	8.30	7.09	5.84	9.93	7.38	9.48	7.04	8.25	7.19	7.77
1974	7.91	8.02	7.93	7.03	8.69	8.16	6.39	8.80	8.22	8.72	8.62	9.16	8.11
1975	6.28	8.72	9.09	6.68	10.11	9.50	7.53	7.14	6.95	7.59	7.39	7.11	7.82
1976	7.91	7.77	8.31	7.40	7.17	7.27	5.80	5.74	5.98	5.59	5.91	6.04	6.67
1977	6.56	5.97	6.38	7.02	6.27	6.35	6.87	5.30	7.11	7.86	7.25	7.96	6.70
1978	7.37	7.79	7.27	7.82	7.00	7.66	7.37	10.23	11.87	8.77	6.68	7.50	8.20
1979	8.44	7.94	6.82	6.08	7.68	7.01	6.49	6.43	7.17	5.63	6.72	6.45	6.88
1980	7.85	7.65	7.33	6.83	7.35	6.74	7.52	6.94	7.48	7.51	8.59	7.85	7.46
1981	6.45	6.54	6.97	5.04	5.73	7.79	6.59	6.76	7.22	7.25	5.70	7.89	6.69
1982	4.60	0.00	5.66	4.42	5.45	6.14	5.63	5.05	3.90	5.87	7.33	4.47	4.85
1983	6.72	6.19	8.23	9.77	8.31	6.56	7.35	7.44	8.72	7.74	9.28	8.35	7.86
1984	7.60	8.29	6.28	5.99	8.18	7.39	5.55	7.74	4.96	9.40	7.93	8.02	7.23
1985	9.06	8.03	7.72	8.18	7.78	10.20	7.81	7.56	6.41	10.13	8.26	8.20	8.23
1986	7.68	10.35	8.72	8.66	9.12	11.85	10.17	7.11	7.03	5.83	6.69	1.13	7.87
1987	4.55	5.60	5.23	3.62	7.03	5.26	6.21	7.73	5.34	9.53	10.06	8.98	6.59
1988	8.88	6.84	5.14	6.24	4.70	5.07	0.82	2.54	0.22	0.00	0.00	0.00	3.40
1989	0.00	0.00	0.00	0.00	0.00	8.50	7.03	7.32	9.53	8.74	8.63	7.49	5.02
1990	10.44	8.38	7.92	5.92	7.09	7.61	4.47	0.00	0.00	0.00	0.00	0.00	4.24
% TOTAL MONTHLY PRODUCTION	5.38	4.94	5.30	4.84	5.10	5.70	5.53	5.27	5.30	5.47	5.46	5.05	

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, UMR #2 WELL: 5.29 PERCENT

Table 18: Percentage of total monthly and yearly production provided by UMR well #2.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #10
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	4.47	7.04	7.10	1.65	6.76	4.64	31.66
1968	4.83	5.06	4.58	5.70	7.06	5.53	7.75	8.14	6.93	7.51	5.93	5.19	74.22
1969	4.96	5.08	3.74	4.23	5.74	7.64	6.26	8.08	6.88	6.67	8.07	9.08	76.43
1970	5.60	7.02	6.00	6.88	5.85	7.99	10.96	10.90	11.84	8.26	5.54	5.25	92.09
1971	4.51	6.60	4.54	6.32	6.46	7.16	8.82	8.60	7.82	6.05	5.52	5.46	77.84
1972	5.28	4.73	5.66	4.71	7.50	8.50	9.46	7.75	7.24	6.37	5.68	5.37	78.25
1973	5.94	4.48	5.36	5.42	5.51	4.38	8.00	7.72	5.83	5.78	5.33	3.87	67.64
1974	4.75	4.78	5.07	4.74	5.19	4.85	8.46	7.38	6.14	5.11	5.06	4.90	66.41
1975	3.64	4.52	6.11	4.69	2.79	0.00	7.27	9.63	6.72	6.64	5.32	5.85	63.17
1976	5.30	5.46	4.24	5.44	6.17	8.10	9.12	7.18	7.84	7.24	6.64	5.98	78.72
1977	6.24	6.21	5.43	5.56	7.71	6.54	6.35	7.64	6.11	6.80	7.38	4.44	76.43
1978	5.44	5.39	6.02	5.72	5.43	10.16	13.51	0.94	0.00	0.00	4.75	5.74	63.09
1979	5.50	4.08	6.57	5.81	6.02	5.47	6.30	6.76	8.41	6.26	6.41	6.86	74.45
1980	5.41	4.57	5.49	5.31	5.36	6.13	11.08	10.50	7.47	7.23	7.20	7.10	82.86
1981	5.50	5.21	4.99	5.39	8.03	5.81	7.53	6.42	8.69	6.48	6.47	6.67	77.20
1982	5.96	6.96	4.63	4.57	5.76	4.13	4.72	5.63	6.89	7.22	4.42	6.55	67.46
1983	5.73	4.92	5.23	4.65	6.27	5.20	6.88	6.95	6.11	6.19	5.01	5.14	68.29
1984	6.10	5.20	5.37	5.14	5.78	4.47	5.91	6.88	6.16	5.61	5.31	5.25	67.19
1985	5.21	5.08	4.87	5.25	6.81	4.54	11.25	8.77	8.53	6.87	9.94	7.11	84.23
1986	5.72	5.07	6.68	5.55	5.56	6.07	7.59	7.34	7.55	5.08	5.88	5.22	73.30
1987	5.50	5.04	5.22	5.35	5.41	5.76	6.74	7.57	8.58	4.84	6.31	4.90	71.22
1988	5.81	0.00	0.00	0.00	0.00	9.30	8.23	9.85	6.89	7.48	4.95	5.73	58.23
1989	5.63	4.74	5.61	5.23	3.64	0.76	0.02	1.22	0.00	3.16	5.35	4.95	40.31
1990	3.19	4.58	3.00	2.88	3.77	4.64	6.48	5.99	5.64	6.80	5.60	5.68	58.24
TOTAL													
MONTHLY	121.77	114.79	114.41	114.53	127.82	133.14	183.16	174.87	161.37	141.30	144.84	136.94	
PRODUCTION													

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #10: 1668.933 MILLION GALLONS

Table 19: Monthly and yearly production, City of Rolla, well #10, 1967-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #10

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	11.55	15.43	14.83	3.91	16.56	12.32	7.05
1968	12.37	12.50	11.71	13.76	16.04	12.90	15.04	17.48	13.70	15.87	12.82	13.21	14.04
1969	12.81	12.27	9.47	9.71	12.62	16.94	12.67	16.22	15.10	14.55	17.16	21.24	14.31
1970	13.38	15.24	13.89	14.87	11.99	16.56	19.14	19.23	20.33	16.44	11.34	11.42	15.56
1971	10.70	13.20	10.36	12.55	12.55	14.03	13.70	14.56	12.67	11.91	11.19	12.22	12.58
1972	14.42	10.28	12.06	10.40	15.84	14.99	15.92	13.70	13.49	12.62	11.42	11.69	13.16
1973	12.14	9.90	11.26	11.99	11.98	9.26	14.08	13.34	10.28	11.96	10.55	9.16	11.41
1974	10.62	11.99	11.93	11.07	12.17	11.16	13.95	12.42	11.93	11.48	10.87	11.87	11.87
1975	7.67	9.06	11.72	10.37	5.57	0.00	10.86	14.96	10.56	10.97	9.31	10.53	9.45
1976	9.80	10.16	7.46	10.20	11.32	14.06	14.29	11.01	10.70	10.88	10.53	10.19	10.92
1977	9.66	9.44	9.08	9.51	12.38	10.23	11.17	12.13	9.94	12.13	12.27	8.50	10.54
1978	10.73	10.55	11.92	10.04	10.36	18.21	20.62	1.64	0.00	0.00	8.02	10.45	9.22
1979	9.83	7.48	10.73	10.66	9.33	9.67	10.13	10.34	12.92	9.34	10.83	10.88	10.21
1980	9.59	8.46	9.67	9.50	9.81	10.33	13.55	14.22	11.27	10.71	12.09	12.78	11.17
1981	9.50	9.40	8.00	9.93	12.52	9.42	12.16	11.22	12.69	10.16	10.78	10.49	10.56
1982	10.41	10.21	7.83	7.84	8.87	6.54	7.72	7.60	8.69	11.36	6.50	11.44	8.71
1983	10.14	8.75	8.70	8.68	10.21	8.65	9.24	7.38	8.58	9.69	8.54	8.79	8.88
1984	10.01	9.50	9.06	8.96	9.68	7.54	8.98	9.25	9.28	9.56	9.59	9.95	9.27
1985	9.26	9.49	8.73	8.89	11.71	8.78	14.95	13.88	11.88	10.46	17.75	12.68	11.66
1986	10.58	10.00	11.59	9.81	9.74	9.99	10.88	11.11	10.81	8.20	11.11	9.16	10.26
1987	10.82	9.29	8.55	9.06	10.01	8.57	10.37	10.73	12.72	7.98	10.75	9.04	9.85
1988	11.12	0.00	0.00	0.00	0.00	11.92	14.44	13.92	11.02	12.44	9.22	11.09	8.01
1989	9.99	9.46	10.09	9.73	5.44	1.30	0.03	1.74	0.00	4.49	8.82	8.25	5.48
1990	5.04	8.84	4.77	5.09	6.47	7.47	10.24	8.87	8.07	10.82	10.25	10.01	7.98
% TOTAL MONTHLY PRODUCTION	8.51	7.80	7.71	7.68	8.11	8.28	10.12	9.54	8.95	8.44	9.14	9.20	

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #10: 8.67 PERCENT

Table 20: Percentage of total monthly and yearly production provided by City of Rolla, well #10

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, HYPOINT WELL #1
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	1.55	4.84	4.70	2.68	3.91	0.00	0.00	6.28	8.37	9.24	8.19	9.04	58.81
1976	4.65	3.75	0.01	4.81	7.14	5.29	4.50	3.57	6.25	5.37	8.79	5.10	59.22
1977	8.12	12.96	10.49	9.95	9.17	1.12	6.38	2.61	4.58	4.04	4.93	4.89	79.25
1978	2.74	3.06	3.38	3.53	3.75	3.05	3.97	3.98	3.81	1.71	4.33	3.36	40.65
1979	4.69	4.16	6.41	5.39	6.25	6.66	9.78	5.80	4.19	5.02	3.69	5.07	67.10
1980	4.26	4.60	2.03	2.16	3.11	2.58	1.96	2.57	5.64	4.10	6.77	4.29	44.08
1981	10.37	4.41	5.44	6.01	7.95	11.49	5.62	0.03	4.77	5.86	8.36	10.41	80.72
1982	6.69	6.98	9.15	11.06	10.93	18.02	9.85	9.39	8.98	3.97	12.14	4.64	111.79
1983	5.33	5.76	8.90	5.68	6.78	4.56	5.85	3.13	7.22	6.14	7.45	6.43	73.24
1984	8.84	6.60	6.63	5.98	6.64	5.10	7.81	11.91	5.04	5.01	6.66	4.40	80.62
1985	4.51	5.09	6.52	6.03	10.62	2.96	2.32	0.00	0.00	0.00	0.00	0.00	38.06
1986	2.02	1.75	2.15	5.91	3.65	4.55	5.08	9.46	3.49	6.69	3.44	4.30	52.48
1987	8.66	4.70	9.68	6.87	5.75	3.88	6.38	7.23	6.79	2.95	8.85	9.45	81.21
1988	6.08	6.67	7.82	5.58	9.64	16.32	17.30	10.58	8.28	12.14	5.84	4.84	111.09
1989	5.39	6.08	5.18	5.12	3.98	5.50	2.37	2.19	1.99	2.14	4.94	3.70	48.58
1990	4.41	3.48	3.32	3.12	2.02	4.14	2.12	6.08	5.37	0.10	0.16	1.76	36.09
TOTAL													
MONTHLY PRODUCTION	88.32	84.88	91.82	89.88	101.30	95.22	91.28	84.81	84.76	74.49	94.52	81.70	

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, HYPOINT WELL #1: 1062.975 MILLION GALLONS

Table 21: Monthly and yearly production, Hypoint well #1, 1975-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, HYPOINT WELL #1

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	3.28	9.69	9.02	5.93	7.82	0.00	0.00	9.76	13.14	15.27	14.33	16.26	8.80
1976	8.59	6.97	0.02	9.01	13.11	9.17	7.05	5.47	8.53	8.07	13.94	8.68	8.22
1977	12.56	19.69	17.53	17.03	14.73	1.75	11.22	4.15	7.45	7.20	8.19	9.36	10.93
1978	5.39	5.98	6.69	6.20	7.15	5.46	6.06	6.96	5.48	2.84	7.32	6.12	5.94
1979	8.39	7.63	10.47	9.89	9.68	11.78	15.70	8.87	6.44	7.49	6.24	8.03	9.20
1980	7.56	8.51	3.57	3.86	5.69	4.35	2.39	3.48	8.52	6.08	11.38	7.73	5.94
1981	17.92	7.97	8.73	11.06	12.40	18.65	9.07	0.04	6.96	9.17	13.92	16.37	11.04
1982	11.68	10.24	15.47	18.97	16.82	28.49	16.13	12.67	11.31	6.24	17.85	8.11	14.43
1983	9.44	10.24	14.79	10.60	11.03	7.58	7.87	3.33	10.14	9.62	12.70	11.00	9.53
1984	14.50	12.04	11.18	10.43	11.11	8.60	11.86	16.02	7.59	8.54	12.02	8.34	11.12
1985	8.02	9.51	11.68	10.22	18.28	5.72	3.09	0.00	0.00	0.00	0.00	0.00	5.27
1986	3.73	3.44	3.73	10.45	6.40	7.49	7.28	14.31	5.00	10.79	6.49	7.56	7.35
1987	17.04	8.67	15.87	11.65	10.64	5.77	9.81	10.25	10.07	4.86	15.08	17.43	11.23
1988	11.63	11.43	13.83	10.00	13.64	20.92	30.37	14.95	13.24	20.19	10.88	9.37	15.27
1989	9.57	12.12	9.32	9.53	5.94	9.43	3.38	3.11	3.15	3.04	8.14	6.17	6.60
1990	6.97	6.72	5.29	5.52	3.46	6.67	3.35	9.01	7.70	0.16	0.29	3.10	4.95
% TOTAL MONTHLY PRODUCTION	6.18	5.77	6.19	6.03	6.43	5.92	5.05	4.63	4.70	4.45	5.97	5.49	

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, HYPOINT WELL #1: 5.52 PERCENT

Table 22: Percentage of total monthly and yearly production provided by Hypoint well #1.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, HYPOINT WELL #2
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	2.60	4.19	3.11	2.51	2.56	8.05	8.38	0.75	0.00	0.00	0.00	0.15	32.31
1976	2.87	5.12	9.42	4.35	3.08	5.10	5.09	5.80	4.42	5.77	4.14	5.95	61.11
1977	1.30	0.49	0.00	0.00	0.04	7.65	1.69	4.12	4.16	4.79	5.38	1.75	31.37
1978	3.77	3.40	0.34	4.81	2.74	4.48	3.14	2.80	3.11	5.17	3.07	4.74	41.57
1979	3.19	3.92	5.10	4.36	8.31	4.00	1.45	3.86	5.32	5.00	6.80	6.20	57.51
1980	6.28	5.03	6.11	4.88	2.10	2.49	3.90	3.59	6.42	8.43	6.12	7.79	63.13
1981	3.86	9.05	9.70	7.65	7.95	5.99	10.94	10.46	6.44	11.65	7.28	7.29	98.25
1982	7.28	11.61	10.40	8.76	9.69	3.93	10.26	10.61	15.18	5.47	5.80	7.59	106.57
1983	6.68	5.47	3.61	7.19	6.94	6.27	10.47	23.75	8.61	6.52	4.76	7.09	97.36
1984	5.56	7.31	8.45	8.53	7.28	6.69	5.10	1.38	7.26	7.01	5.60	8.44	78.60
1985	9.77	8.31	6.54	7.19	0.00	0.00	0.11	4.06	4.24	4.92	4.63	4.20	53.97
1986	1.96	2.04	3.15	6.00	2.11	4.92	6.91	2.24	7.75	3.66	6.21	6.31	53.26
1987	6.17	10.29	7.01	9.03	1.09	11.54	6.63	6.84	8.06	11.99	5.26	3.59	87.52
1988	5.49	5.82	5.05	6.49	9.64	0.00	0.00	0.00	0.00	1.43	8.04	5.19	47.15
1989	6.07	6.72	7.51	6.11	1.58	4.08	6.15	3.88	2.05	3.95	4.22	5.73	58.05
1990	4.35	2.68	4.18	3.12	4.83	3.36	3.21	1.73	0.01	4.64	3.73	1.57	37.42
TOTAL													
MONTHLY	77.22	91.44	89.69	90.97	69.93	78.55	83.42	85.86	83.03	90.40	81.05	83.56	
PRODUCTION													

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, HYPOINT WELL #2: 1005.125 MILLION GALLONS

Table 23: Monthly and yearly production, Hypoint well #2, 1975-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, HYPOINT WELL #2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	5.50	8.39	5.97	5.54	5.13	14.47	12.52	1.17	0.00	0.00	0.00	0.27	4.83
1976	5.31	9.53	16.59	8.15	5.65	8.84	7.97	8.90	6.03	8.67	6.57	10.13	8.48
1977	2.02	0.75	0.00	0.00	0.06	11.95	2.98	6.54	6.77	8.54	8.94	3.34	4.33
1978	7.44	6.65	0.67	8.45	5.22	8.04	4.79	4.89	4.48	8.59	5.19	8.63	6.08
1979	5.71	7.19	8.33	8.00	12.87	7.08	2.32	5.90	8.17	7.46	11.49	9.83	7.89
1980	11.14	9.30	10.76	8.72	3.83	4.20	4.77	4.86	9.69	12.49	10.28	14.02	8.51
1981	6.66	16.33	15.56	14.08	12.40	9.72	17.67	18.27	9.40	18.24	12.12	11.46	13.44
1982	12.70	17.03	17.57	15.04	14.92	6.21	16.80	14.31	19.13	8.60	8.53	13.25	13.76
1983	11.83	9.72	6.01	13.42	11.29	10.42	14.07	25.22	12.10	10.21	8.12	12.12	12.66
1984	9.11	13.34	14.26	14.87	12.18	11.27	7.74	1.86	10.94	11.93	10.12	15.98	10.84
1985	17.37	15.52	11.72	12.18	0.00	0.00	0.14	6.43	5.91	7.48	8.27	7.50	7.47
1986	3.62	4.02	5.47	10.61	3.70	8.11	9.90	3.39	11.09	5.90	11.74	11.08	7.46
1987	12.14	18.98	11.49	15.31	2.01	17.15	10.19	9.70	11.96	19.77	8.97	6.62	12.10
1988	10.51	9.97	8.92	11.64	13.64	0.00	0.00	0.00	0.00	2.38	14.99	10.04	6.48
1989	10.77	13.40	13.49	11.37	2.36	6.99	8.75	5.51	3.25	5.62	6.97	9.55	7.89
1990	6.89	5.17	6.66	5.51	8.28	5.41	5.08	2.56	0.01	7.39	6.83	2.77	5.13
%													
TOTAL													
MONTHLY	5.40	6.22	6.05	6.10	4.44	4.88	4.61	4.69	4.61	5.40	5.12	5.61	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, HYPOINT WELL #2: 5.22 PERCENT

Table 24: Percentage of total monthly and yearly production provided by Hypoint Well #2.

CITY OF ROLLA, WELL #11
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.22	7.18	12.40
1973	7.82	7.12	6.14	5.56	6.53	9.75	7.47	7.40	8.60	7.64	7.47	6.48	87.99
1974	6.04	6.31	6.11	6.05	5.98	5.81	9.29	6.46	7.03	6.74	7.60	5.73	79.15
1975	5.95	6.12	0.00	6.00	7.66	9.28	9.73	8.12	7.70	6.82	7.22	7.06	81.67
1976	7.48	4.04	7.64	5.42	7.66	6.28	7.87	8.52	9.57	5.96	7.48	6.62	84.53
1977	7.95	6.95	6.73	6.83	9.19	7.53	5.58	5.44	7.44	2.51	6.45	6.58	79.19
1978	7.35	7.33	7.05	7.13	7.11	7.82	7.81	9.48	12.45	13.42	9.63	7.20	103.79
1979	8.18	6.01	7.24	7.15	7.22	6.99	7.68	9.12	8.40	7.85	5.92	7.88	89.65
1980	7.69	6.91	6.84	6.19	6.60	6.78	7.06	0.61	0.00	0.00	0.00	0.04	48.72
1981	4.18	6.12	5.74	4.44	5.22	2.63	0.00	0.00	0.00	0.00	0.36	1.26	29.95
1982	8.01	7.57	6.31	6.13	6.54	7.14	6.25	6.74	7.31	6.60	6.61	6.79	82.02
1983	7.17	7.72	6.98	0.34	0.00	6.10	4.48	8.24	6.75	8.19	6.72	7.47	70.17
1984	6.90	7.19	8.09	7.90	7.74	8.53	9.38	10.57	8.97	7.75	6.28	6.45	95.75
1985	6.36	7.53	7.65	7.78	8.17	5.87	13.48	9.66	12.21	9.86	6.89	8.74	104.19
1986	6.84	6.86	6.65	6.92	8.38	6.79	7.41	8.47	7.39	7.62	5.65	7.54	86.52
1987	5.96	6.90	7.51	7.24	7.62	9.07	7.80	7.27	10.84	7.13	6.88	6.45	90.68
1988	6.94	8.73	9.44	7.88	9.70	11.99	5.75	10.40	10.97	7.21	7.62	8.84	105.48
1989	9.68	6.76	9.04	9.01	13.44	8.82	11.10	12.96	10.86	13.22	10.76	12.94	128.58
1990	9.65	6.86	6.89	6.34	6.75	8.25	8.81	9.26	12.02	12.87	10.66	12.56	110.93
TOTAL													
MONTHLY PRODUCTION	130.15	123.03	122.07	114.31	131.51	135.44	136.96	138.74	148.52	131.40	125.41	133.83	

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #11: 1571.358 MILLION GALLONS

Table 25: Monthly and yearly production, City of Rolla, well #11, 1972-1991.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #11

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.49	15.63	2.08
1973	15.98	15.72	12.90	12.29	14.19	20.59	13.14	12.79	15.17	15.81	14.80	15.33	14.84
1974	13.50	15.84	14.39	14.15	14.02	13.38	15.31	10.88	13.66	15.15	16.33	13.89	14.14
1975	12.56	12.25	0.00	13.28	15.32	16.68	14.55	12.61	12.09	11.27	12.63	12.70	12.22
1976	13.82	7.52	13.45	10.16	14.05	10.89	12.32	13.07	13.06	8.96	11.86	11.28	11.73
1977	12.30	10.55	11.25	11.69	14.76	11.77	9.82	8.64	12.10	4.48	10.72	12.60	10.93
1978	14.49	14.35	13.97	12.52	13.56	14.03	11.93	16.59	17.94	22.27	16.27	13.10	15.18
1979	14.63	11.01	11.82	13.12	11.18	12.37	12.34	13.96	12.90	11.72	10.00	12.49	12.29
1980	13.63	12.79	12.04	11.07	12.07	11.42	8.64	0.83	0.00	0.00	0.00	0.07	6.57
1981	7.22	11.04	9.22	8.17	8.14	4.28	0.00	0.00	0.00	0.00	0.59	1.98	4.10
1982	13.98	11.10	10.67	10.52	10.07	11.29	10.24	9.10	9.21	10.39	9.72	11.87	10.59
1983	12.70	13.72	11.60	0.63	0.00	10.15	6.01	8.75	9.48	12.83	11.46	12.78	9.13
1984	11.32	13.13	13.65	13.76	12.96	14.37	14.26	14.21	13.52	13.20	11.34	12.22	13.21
1985	11.30	14.07	13.70	13.17	14.06	11.34	17.92	15.30	17.00	15.01	12.30	15.61	14.42
1986	12.66	13.54	11.55	12.22	14.68	11.18	10.62	12.82	10.58	12.29	10.67	13.24	12.11
1987	11.72	12.72	12.30	12.28	14.10	13.49	11.98	10.31	16.07	11.76	11.74	11.90	12.54
1988	13.28	14.97	16.68	14.12	13.73	15.37	10.09	14.70	17.55	12.00	14.20	17.11	14.50
1989	17.19	13.49	16.25	16.76	20.09	15.12	15.80	18.40	17.23	18.78	17.73	21.58	17.48
1990	15.25	13.24	10.97	11.22	11.57	13.28	13.93	13.72	17.23	20.50	19.53	22.14	15.21
% TOTAL													
MONTHLY	9.10	8.36	8.23	7.67	8.35	8.42	7.57	7.57	8.24	7.85	7.92	8.99	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #11: 8.16 PERCENT

Table 26: Percentage of total monthly and yearly production provided by City of Rolla, well #11.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #12
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.00	4.80	11.15	9.77	4.50	4.63	6.22	5.61	7.28	7.35	7.91	6.32	75.55
TOTAL													
MONTHLY	0.00	4.80	11.15	9.77	4.50	4.63	6.22	5.61	7.28	7.35	7.91	6.32	
PRODUCTION													

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #12: 75.549 MILLION GALLONS

Table 27: Monthly and yearly production, City of Rolla, well #12, 1990.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #12

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.00	9.28	17.75	17.27	7.71	7.46	9.84	8.31	10.43	11.70	14.49	11.14	10.36
%													
TOTAL													
MONTHLY	0.00	0.33	0.75	0.66	0.29	0.29	0.34	0.31	0.40	0.44	0.50	0.42	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #12: 0.39 PERCENT

Table 28: Percentage of total monthly and yearly production provided by City of Rolla, well #12.

Ozark Aquifer in the Rolla Area

CITY OF ROLLA, WELL #13
WELL PRODUCTION (MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.00	1.01	5.51	5.93	7.13	6.75	8.44	8.72	12.39	12.67	11.16	10.81	90.52
TOTAL													
MONTHLY	0.00	1.01	5.51	5.93	7.13	6.75	8.44	8.72	12.39	12.67	11.16	10.81	
PRODUCTION													

TOTAL PRODUCTION 1957-1990, CITY OF ROLLA, WELL #13: 90.522 MILLION GALLONS

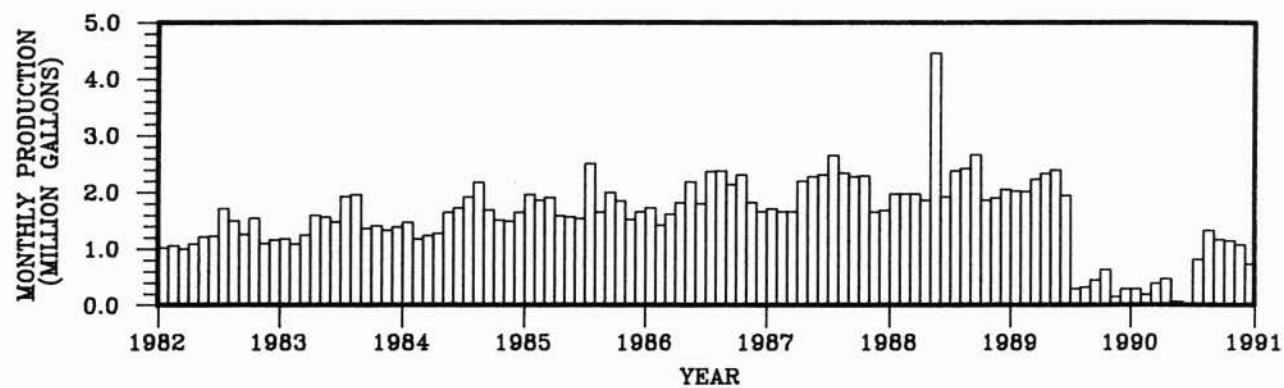
Table 29: Monthly and yearly production, City of Rolla, well #13, 1990.

PERCENT OF TOTAL CITY PRODUCTION
SUPPLIED BY CITY OF ROLLA, WELL #13

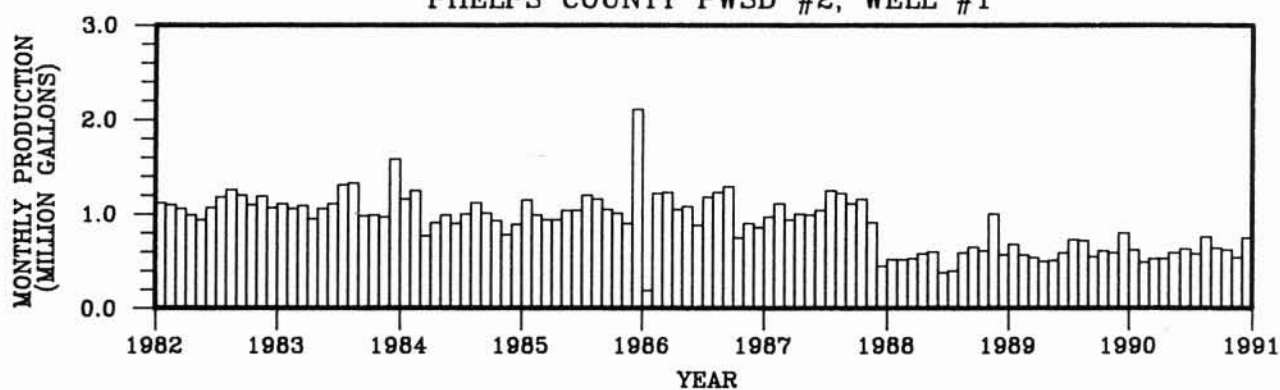
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY PERCENTAGE
1957	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.00	1.96	8.78	10.49	12.23	10.87	13.35	12.93	17.75	20.17	20.43	19.04	12.41
%													
TOTAL													
MONTHLY	0.00	0.07	0.37	0.40	0.45	0.42	0.47	0.48	0.69	0.76	0.70	0.73	
PRODUCTION													

PERCENTAGE OF TOTAL PRODUCTION FROM 1957 THROUGH 1990 SUPPLIED BY CITY OF ROLLA, WELL #13: 0.47 PERCENT

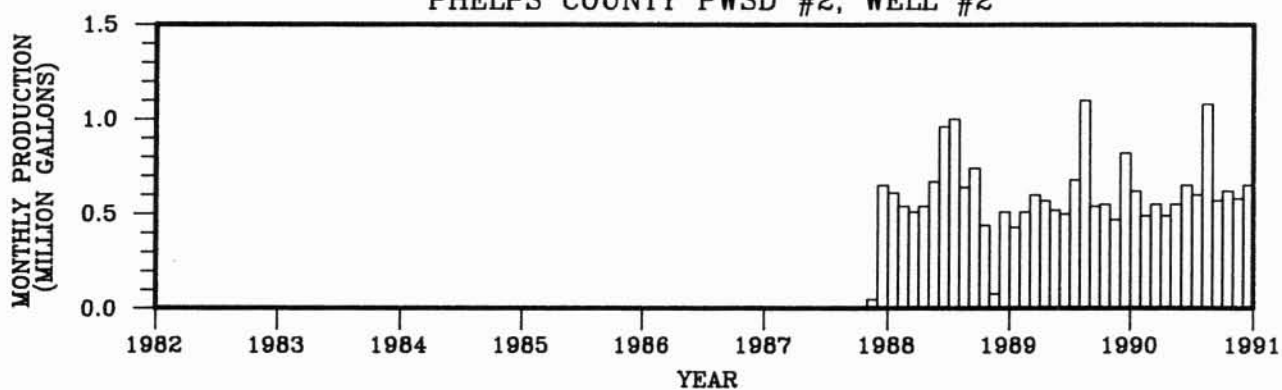
Table 30: Percentage of total monthly and yearly production provided by City of Rolla, well #13.



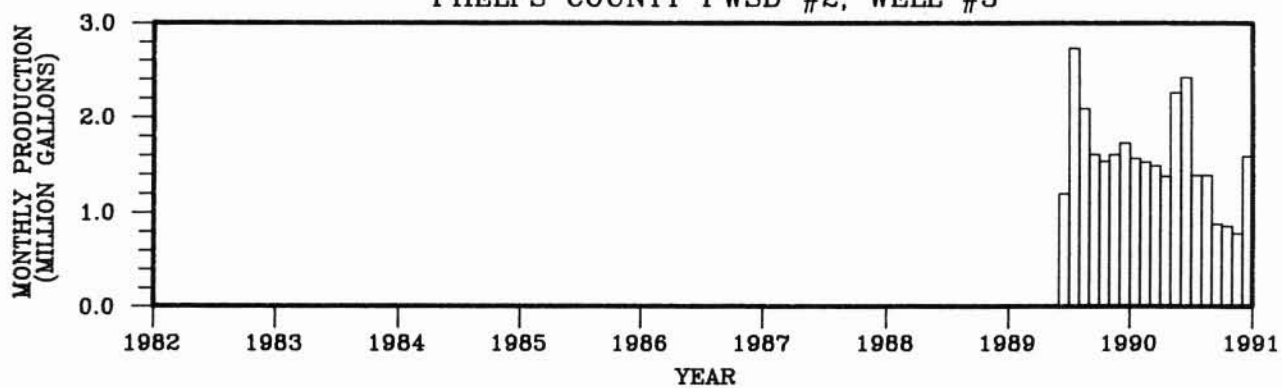
PHELPS COUNTY PWSD #2, WELL #1



PHELPS COUNTY PWSD #2, WELL #2



PHELPS COUNTY PWSD #2, WELL #3



PHELPS COUNTY PWSD #2, WELL #4

Figure 4: Monthly production, Phelps County PWSD #2 wells #1, #2, #3, and #4.

20.1 gpm/ft. From 1982 to 1991, well #2 produced 97.7 million gallons, and has supplied about 30 percent of the District's water. It is currently pumped at about 180 gpm.

Well #3 was drilled in 1987 to a total depth of 1,250 ft, and contains 520 ft of 10-in. diameter casing. The well was tested at 302 gpm and 402 gpm pumping rates, and had 26 ft and 38 ft of drawdown, respectively. Based on the two pumping tests specific capacity is 11 gpm/ft. Static water level at the time of drilling was 374 ft. In July, 1992, water level was 387 ft, indicating a water-level decline of about 13 feet over the past 5 years, or about 2.6 ft/yr. Production from well #3 began November, 1987, and between then and 1991 had totalled 22.6 million gallons. Pumping rate of the well is currently about 170 gpm.

Well #4 is the District's newest well. Drilled in 1988, it has a total depth of 1,150 ft and contains 446 ft of 10-in. diameter casing. Upon completion, the well was tested at 500 gpm and had a specific capacity of 19.6 gpm/ft. Production from well #4 was added to the system beginning March, 1989, and between then and 1991 the well produced about 30.1 million gallons. Well #3 is the District's most productive well, and is presently pumped at about 320 gpm.

CITY OF ST. JAMES WELLS

The City of St. James has had a public water supply system since about 1924. St. James has had 5 wells, but currently produces from three: Well #1, well #2B, and

well #4. A fourth well (well #3) is apparently inactive, and another (well 2A) was abandoned and plugged in 1969.

St. James well #1 was drilled in 1924 to a total depth of 700 ft, and contains 168 ft of 8-in. diameter casing. The well was deepened in 1965 to 1,100 ft, and recased with 302 ft of 12-in. diameter casing. After deepening, the well yielded 300 gpm with about 115 ft of drawdown; specific capacity was 2.6 gpm/ft. The well was acidized in 1967 which improved the specific capacity to 3.0 gpm/ft. In 1924, static water level was 80 ft. In 1967, water level was 223.5 ft., a decrease of 143 ft and an average water-level decline of 3.3 ft/yr.

Well 2A was drilled in 1947 to a depth of 1,100 ft, and contained 295 ft of 10-in. diameter casing. Its yield was about 360 gpm, and static water level was about 198 ft. The well was plugged and abandoned in 1969. Well 2B was drilled in 1969 to replace 2A; the wells are only about 15 feet apart. Well 2B is 1,100 ft deep, and contains 316 ft of 12-in. diameter casing. Static water level in 1969 was 215 ft, and the well yields about 500 gpm.

Well #3 was constructed in 1961, is 1,100 ft deep, and contains 303 ft of 12-in. diameter casing. It is capable of producing about 500 gpm.

Well #4 was drilled in 1984. It is 1,100 ft deep and contains 300 ft of 12-in. diameter casing. Static water level when the well was drilled was 178 ft. It was pump tested at 550 gpm, and there was 83 ft of drawdown; specific capacity was 6.6 gpm/ft.

WATER USE FROM THE OZARK AQUIFER IN THE ROLLA AREA

INTRODUCTION

The volume of water produced each year from the Ozark aquifer in the Rolla area has increased many fold since the first City well was drilled. Before the first water-supply well was drilled, residents supplied themselves using cisterns that stored roof runoff, and probably some shallow, hand-dug wells were available that supplied low volumes of water. Per capita water use was undoubtedly much lower then than today.

Water supply in the rural area was not much different. Cisterns, shallow wells, streams, and springs were common sources of water. There were few water-well drilling rigs in operation at that time, and most people simply could not afford a well. Drilling records on file at the Division of Geology and Land Survey show a sharp increase in the number of private wells drilled beginning about 1950.

POPULATION TRENDS

The populations of Phelps County, Rolla, and St. James have changed greatly during the last century. In 1890, Phelps County had a population of 12,636. Rolla's population was 1,592 and St. James had a population of 467. Except from 1910 to 1920, census information shows Phelps County and Rolla population to have steadily increased. In 1990, Phelps County had a population of 35,248 and Rolla's population was 14,090. St. James population has increased each census except for between 1980 and 1990. St. James 1990 population was 3,256, slightly below the 1980 population of 3,328 (table 31 and figure 5).

Census data are collected and tabulated for each political township. The townships adjacent to Rolla are Rolla township (T. 37 N., R. 8 W.) which includes most of the City of Rolla, Dillon township (T. 37 N., R. 7 W.

and T. 38 N., R. 7 W.) which includes the eastern part of Rolla, and Miller township (T. 38 N., R. 8 W. and portions of T. 38 N., R. 9 W. and T. 38 N., R. 10 W.) which includes the northern part of Rolla. Census data lists the total population within each of these townships, and also the population in each township within the City of Rolla. For the purposes of this study, the combined populations of Rolla, Dillon, and Miller townships, less the population in each township within Rolla and St. James, is considered the rural Rolla population.

In 1890, the rural Rolla population was 3,623. Between 1890 and 1950, rural population fluctuated but had a slight net loss. Rural population began increasing between 1950 and 1960, and nearly tripled in the 40 years between 1950 and 1990 to 9,271 in 1990.

In 1990, the population of Rolla and rural Rolla totaled 23,361, representing 66.3 percent of the Phelps County population. It is the water use within this area that has had the greatest impact on groundwater levels in the Rolla area.

POPULATION (upper number)
PERCENTAGE CHANGE IN POPULATION FROM PREVIOUS CENSUS
(lower number)

Year	Rolla	St. James	Rural Rolla	Phelps County
1890	1,592	467	3,623	12,636
1900	1,600 (+0.5)	575 (+23.1)	3,899 (+7.6)	14,194 (+12.3)
1910	2,261 (+41.3)	1,100 (+91.3)	3,599 (-7.7)	15,786 (+11.2)
1920	2,077 (-8.1)	1,117 (+1.6)	3,291 (-8.6)	14,941 (-5.4)
1930	3,670 (+76.7)	1,294 (+15.9)	3,183 (-3.3)	15,308 (+2.5)
1940	5,141 (+40.1)	1,812 (+40.0)	3,177 (-0.2)	17,437 (+13.9)
1950	9,354 (+82.0)	1,996 (+10.2)	3,608 (+13.6)	21,504 (+23.3)
1960	11,132 (+19.0)	2,384 (+19.4)	5,012 (+38.9)	25,396 (+18.1)
1970	13,245 (+19.0)	2,787 (+16.9)	6,613 (+31.9)	29,481 (+16.1)
1980	13,303 (+0.4)	3,328 (+19.4)	8,903 (+34.6)	33,633 (+14.1)
1990	14,090 (+5.9)	3,256 (-2.2)	9,271 (+4.1)	35,248 (+4.8)

Table 31: Population and percentage change in population, 1980-1990, Rolla, St. James, rural Rolla, and Phelps County. (Source: U.S. Census data)

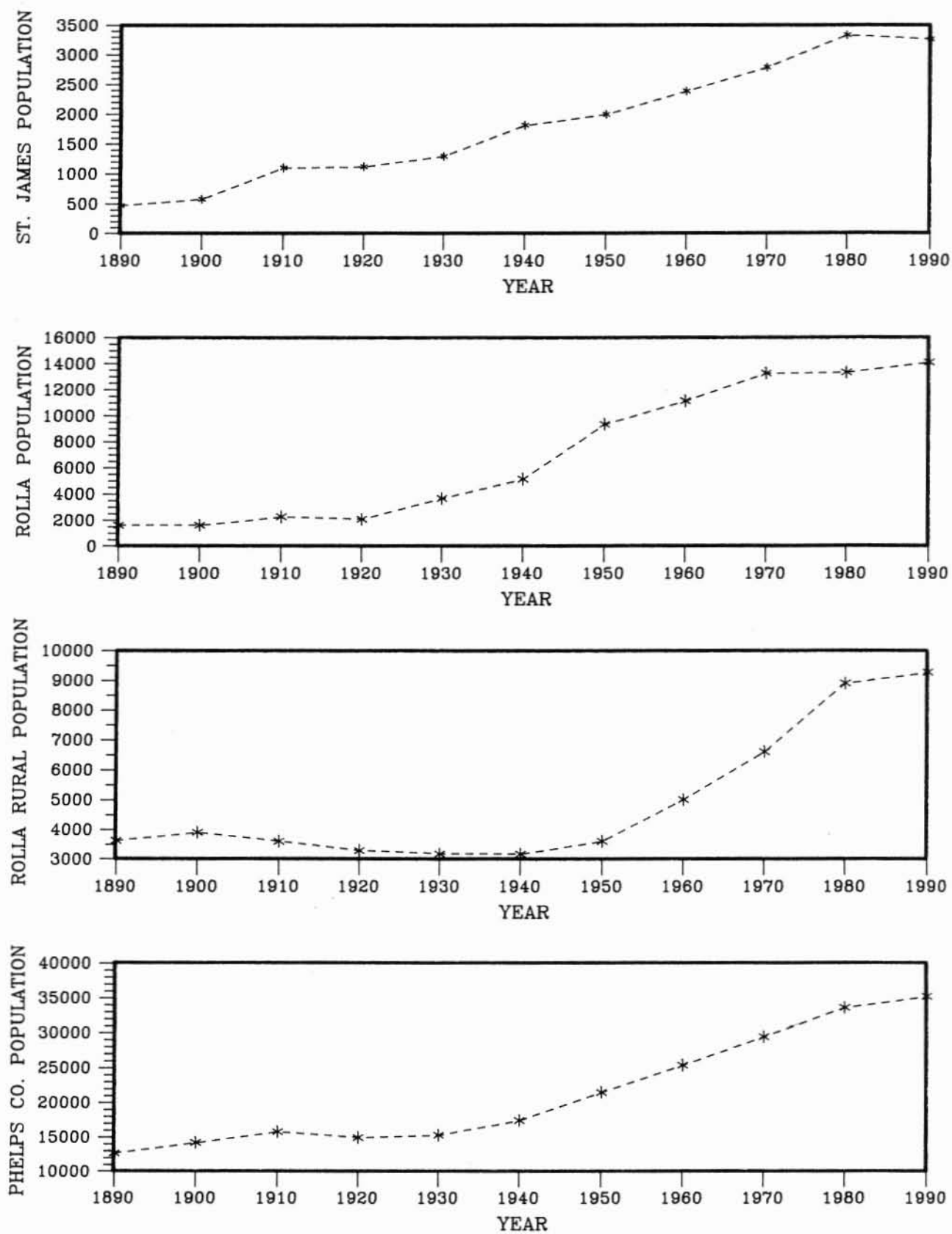


Figure 5: Population trends for Rolla, rural Rolla, St. James, and Phelps County.

WATER USE

The City of Rolla has kept water-use records since it purchased the water system in 1945. In 1945, the City used about 120 million gallons of water. Water use increased nearly steadily until about 1976 when yearly water use was 721 million gallons. Since 1976, water use has fluctuated between 684 million gallons and 774 million gallons. Water use in 1990 was about 730 million gallons. The City has produced an estimated 23 billion gallons since 1907 when its first well was constructed. From 1945 to 1991, the City produced 21.5 billion gallons. Between 1957 and 1991 production was 19.2 billion gallons. Monthly and yearly water use information for 1957 through 1990 for Rolla is shown in tables 32 and 33, and on figure 6. Yearly water use for Rolla, St. James, and Phelps County PWSD #2 is shown on table 34.

Per capita water use is commonly calculated by dividing the average daily volume of water used by a city, by the population of the city. It is typically reported as gallons per day per capita (gpd/c). However, reported water use generally includes water consumed by businesses and industries, so per capita water use includes more than just domestic supply. Cities with businesses or industries that use considerable water typically have much higher per capita use rates than those with little industry.

Per capita water use in Rolla has increased substantially since 1950 when it was about 52 gpd/c. In 1960 and 1970, per capita use was 71 gpd/c and 122 gpd/c, respectively. Per capita use peaked about 1980 when it reached about 153 gpd/c, and it decreased in 1990 to 142 gpd/c.

Annual water-use data were supplied by the City of St. James for 1962 through 1990. Water use in St. James has increased from 68.9 million gallons in 1962 to 128.1 million gallons in 1990. Water use peaked in 1980 when it reached 150.0 million gallons. Total water use for the City of St. James for 1962 through 1990 was 3.329 billion gallons (table 34 and figure 7). St. James per capita water use is somewhat lower than that for Rolla. Per capita water use in St. James in 1970 was 93 gpd/c. In 1980 and 1990 it was 124 gpd/c and 108 gpd/c, respectively.

The amount of water that has been used in the rural Rolla area can only be estimated from population data and by using an assumed per capita use rate. A relatively small portion of the rural Rolla area is supplied water by Phelps County PWSD #2. From 1982 through 1990, PWSD #2 used about 321.6 million gallons (table 34 and figure 8). In 1990, the district produced about 40 million gallons. Currently, PWSD #2 has about 496 active customers, but the total number of people served by the district is not known. About 15 to 20 of their service connects are businesses, but most of the water is used for residential supply (Betty Harris, 1992; personal communication). Based on an estimated 3 people per service connection, per capita use for the district is about 75 gpd/c. Using this per capita use rate and a population of 9,271, current rural Rolla water use is estimated to be 254 million gallons per year.

Combined water use in 1990 for the City of Rolla and rural Rolla is estimated to be 983.5 million gallons, of which 74 percent is water produced and used by the City of Rolla.

WATER-LEVEL CHANGES IN THE OZARK AQUIFER IN THE ROLLA AREA

Water wells producing from the Ozark aquifer in the Rolla area during the last 90 years have produced an estimated 32.6 billion gallons of water. Current yearly production from the aquifer in Rolla and rural Rolla (not including St. James) is nearly 1 billion gallons. Prior to significant groundwater withdrawals, the Ozark aquifer was under steady-state conditions where discharge balanced recharge with no long-term change in groundwater levels. Recharge to the Ozark aquifer is from precipitation. Recharge estimates by Imes and Emmett (in press) indicate that yearly recharge to the Ozark aquifer in the Rolla area may range from 40 million gallons per square mile to as much as 165 million gallons per square mile.

Rolla Municipal Utilities has been collecting water-level data for the City of Rolla wells since 1957. Hydrographs of City wells #2 through #12, and UMR #2 were prepared using average monthly static water-

level values. These hydrographs are shown in figures 9 through 19. Along with water-level information, each figure also shows monthly water production for the well.

The Division of Geology and Land Survey has maintained groundwater-level observation wells in the Rolla area for many years. A continuously operating water-level recorder was installed in the Rolla Holiday Inn (now Rolla Inn) well in 1968. This well is 974 ft deep, contains 420 ft of casing, and bottoms in the Eminence Dolomite. It is on the extreme west edge of the City, and is about 3,500 ft from the nearest City well (well #9). When drilled, static water level in this well was 145 ft. In July, 1992, static water level was 179 ft, a decline of 34 ft and an average decline of 1.1 ft/year (figure 20). The hydrograph of this well shows seasonal drawdown and recovery. Water-level lowers during the summer, due to increased pumping from the Ozark aquifer and little groundwater recharge, then recovers

during the fall and winter when pumping rates are lowest and recharge is greatest.

The Division of Geology and Land Survey has maintained another groundwater-level observation well at Hypoint Industrial Park since 1975. This well, which is 800 ft deep and contains 400 ft of casing, is about 1,300 east of Hypoint well #1, and 2,000 ft north of Hypoint well #2. Its proximity to these two wells cause major short-term fluctuations in water level, thus average monthly water-level data were used in constructing the hydrograph for the well (figure 21). When Hypoint well #3 was drilled in 1968, static water level was about 250 ft. Water level was about 300 ft in July, 1992, indicating a water-level decline of 50 ft, or an average yearly decline of 2.1 ft/year during the period.

Imes (1990), using historic water-level data, constructed a predevelopment potentiometric map for the Ozark aquifer. A potentiometric map is a contour map that connects points of equal groundwater-level elevation. The map shows water levels in the aquifer prior to the development of high-yield wells and before there was significant groundwater withdrawals from the aquifer. This map shows predevelopment water levels in the Ozark aquifer to have varied from about 800 ft above sea level southwest of Rolla, to about 1000 ft above sea level in the Hypoint Industrial Park area northeast of Rolla (figure 22).

Potentiometric maps were constructed for the Rolla area using City of Rolla water-level data, and water-level measurements from well logs at Division of Geology and Land Survey. Maps were constructed to show the configuration of the potentiometric surface in August 1960 (figure 23), August 1970 (figure 24), August 1980 (figure 25), and August 1990 (figure 26). Data from August were used because drawdown effects from seasonal pumpage are typically greatest at that time. The quantity of water-level data was not great for the 1960 and 1970 potentiometric maps. Data availability increased with the drilling of additional wells to supply the City, PWSD #2, and others. Water-level data from relatively shallow private wells in the area were used as a guide if no other nearby data were available.

The potentiometric maps show that from 1960 to 1990, the Ozark aquifer potentiometric surface at Rolla has lowered each of the 10-year periods examined. In 1960, water levels in the City were generally between 760 ft and 850 ft above sea level. In 1990, static water levels were from about 633 ft to 825 ft above sea level.

A potentiometric map to show current water-level conditions was constructed from data collected during July and August, 1992, from Rolla wells, Phelps Co. PWSD #2 wells, and DGLS-U.S. Geological Survey (USGS) observation wells, and a few privately owned wells in the area (figure 27). This potentiometric map shows groundwater levels to be deepest along a north-east-trending zone between I-44 and the Burlington Northern Railroad. Pumping cones developed around City wells #9 and #10 had minimum water-surface elevations of 613 ft and 606 ft above sea level, respectively.

Two maps were prepared showing water-level decline in the Rolla area. The first (figure 28) shows water-level decline between predevelopment and 1992. The second (figure 29) shows water-level decline in the Ozark aquifer in the Rolla area between 1960 and 1992. Figure 28 shows that water-level decline may be as much as 275 ft near heavily pumped wells. The greatest water-level decline is within the City. Water-level decline in the rural Rolla area is thought to be less than 100 ft in most areas, to as much as 150 ft near parts of the City corporate boundaries. The predevelopment potentiometric map was based on relatively few data, and water levels may actually have been somewhat lower than what is indicated on the predevelopment potentiometric map. Most of the water production from the Ozark aquifer has taken place since 1960, and it is likely that the greatest amount of drawdown has also been during the 1960 to 1992 period. The 1960-1992 water-level decline map (figure 28) shows the greatest water-level decline to be along a line paralleling I-44. Maximum water-level decline during this period is about 200 ft near City wells #9 and #10. Water-level decline is much less in the eastern and southern parts of Rolla where it was generally 70 ft to 100 ft. Water-level decline in most of the rural area around Rolla appears to be less than 75 ft.

SUMMARY AND CONCLUSIONS

Groundwater withdrawals in and near Rolla have caused local but significant water-level declines in the Ozark aquifer. Since 1900, the City of Rolla has pumped an estimated 23.5 billion gallons from the Ozark aquifer. The rural Rolla area, which includes the unincorporated parts of Miller, Rolla, and Dillon townships, has produced an estimated 9.1 billion gallons. Combined, water use from the Ozark aquifer from 1900 to present in the Rolla area is conservatively estimated at 32.6 billion

gallons. Current production from the aquifer in Rolla and rural Rolla is about 1 billion gallons per year, not including production by the City of St. James. About 74 percent of the water is produced by the City of Rolla. Because of the distance between the two towns, pumping in St. James probably has little or no effect on Ozark aquifer water levels at Rolla, and production in Rolla likely has no effect on St. James.

Ozark Aquifer in the Rolla Area

COMBINED PRODUCTION, CITY OF ROLLA WELLS
(MILLION GALLONS)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL
1957	0.00	19.90	18.05	21.33	20.78	24.98	26.24	27.98	26.17	22.36	21.50	20.37	249.66
1958	19.56	22.24	19.75	21.34	20.64	22.83	22.21	23.84	25.17	24.21	22.95	21.63	266.37
1959	21.04	22.58	20.68	23.14	24.56	29.00	29.80	31.31	26.93	25.56	25.01	22.34	301.93
1960	21.65	22.08	21.04	23.72	23.45	25.86	28.21	25.45	27.05	25.62	24.22	21.91	290.25
1961	22.38	23.74	18.90	23.38	23.40	19.23	24.24	26.91	26.61	26.10	24.54	21.49	280.92
1962	23.42	25.54	22.59	26.81	29.58	27.54	30.83	32.79	29.09	26.09	24.88	24.04	323.19
1963	23.67	26.73	23.11	26.48	26.40	27.68	29.03	28.03	28.49	32.91	27.50	23.91	323.92
1964	25.21	25.15	24.15	26.59	27.80	27.94	32.14	36.07	33.20	30.51	30.55	25.57	344.88
1965	26.05	27.07	24.68	26.86	34.19	29.33	34.28	33.07	28.90	31.63	31.88	28.78	356.72
1966	28.67	31.08	29.21	32.49	31.91	34.58	53.12	37.87	35.74	39.82	35.08	31.57	421.13
1967	31.62	33.05	30.78	34.76	32.89	33.01	38.67	45.62	47.88	42.28	40.81	37.64	449.02
1968	39.06	40.48	39.15	41.41	44.04	42.88	51.52	46.56	50.62	47.32	46.23	39.31	528.58
1969	38.69	41.43	39.51	43.58	45.49	45.13	49.44	49.81	45.55	45.80	47.05	42.74	534.23
1970	41.89	46.06	43.17	46.26	48.76	48.27	57.28	56.69	58.27	50.22	48.87	45.98	591.71
1971	42.18	49.99	43.84	50.38	51.47	51.00	64.39	59.05	61.67	50.79	49.32	44.64	618.71
1972	36.62	45.95	46.90	45.33	47.34	56.67	59.39	56.60	53.69	50.49	49.78	45.91	594.68
1973	48.95	45.30	47.59	45.21	45.98	47.35	56.85	57.88	56.71	48.30	50.51	42.29	592.92
1974	44.75	39.83	42.47	42.78	42.67	43.46	60.65	59.42	51.44	44.51	46.53	41.24	559.74
1975	47.39	49.95	52.14	45.19	50.03	55.65	66.90	64.35	63.70	60.53	57.16	55.58	668.57
1976	54.11	53.75	56.80	53.37	54.50	57.63	63.86	65.19	73.25	66.54	63.06	58.73	720.79
1977	64.59	65.84	59.85	58.43	62.24	63.96	56.86	63.01	61.49	56.08	60.17	52.27	724.80
1978	50.74	51.10	50.46	56.92	52.43	55.77	65.52	57.14	69.44	60.25	59.19	54.95	683.90
1979	55.94	54.53	61.26	54.48	64.56	56.55	62.27	65.35	65.08	67.02	59.16	63.08	729.28
1980	56.38	54.03	56.83	55.92	54.69	59.34	81.75	73.84	66.25	67.54	59.55	55.54	741.67
1981	57.90	55.41	62.30	54.32	64.12	61.62	61.92	57.24	68.50	63.85	60.04	63.61	730.83
1982	57.32	68.18	59.16	58.28	64.98	63.23	61.08	74.12	79.34	63.59	68.00	57.23	774.49
1983	56.51	56.26	60.17	53.60	61.47	60.10	74.43	94.18	71.19	63.84	58.65	58.51	768.91
1984	60.97	54.80	59.27	57.38	59.72	59.37	65.81	74.37	66.35	58.73	55.36	52.80	724.93
1985	56.24	53.52	55.84	59.05	58.11	51.74	75.23	63.16	71.81	65.69	56.03	56.03	722.44
1986	54.06	50.70	57.58	56.57	57.11	60.75	69.78	66.10	69.83	62.00	52.91	56.91	714.30
1987	50.85	54.23	61.02	58.99	54.04	67.29	65.07	70.53	67.46	60.66	58.66	54.24	723.04
1988	52.26	58.32	56.60	55.81	70.65	78.01	56.97	70.78	62.51	60.12	53.65	51.66	727.35
1989	56.33	50.12	55.63	53.73	66.90	58.32	70.25	70.45	63.06	70.38	60.66	59.97	735.81
1990	63.23	51.81	62.83	56.56	58.30	62.13	63.24	67.46	69.80	62.80	54.61	56.76	729.53
TOTAL													
MONTHLY	1430.23	1470.77	1483.29	1490.44	1575.19	1608.22	1809.25	1832.17	1802.25	1674.15	1584.05	1489.21	
PRODUCTION													

COMBINED PRODUCTION 1957-1990, CITY OF ROLLA WELLS: 19249.21 MILLION GALLONS

Table 32: Combined production, City of Rolla wells, 1957-1991.

MONTHLY PERCENTAGE OF YEARLY WATER USE, CITY OF ROLLA												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1957	0.00	7.97	7.23	8.55	8.32	10.01	10.51	11.21	10.48	8.96	8.61	8.16
1958	7.34	8.35	7.41	8.01	7.75	8.57	8.34	8.95	9.45	9.09	8.61	8.12
1959	6.97	7.48	6.85	7.66	8.13	9.60	9.87	10.37	8.92	8.46	8.28	7.40
1960	7.46	7.61	7.25	8.17	8.08	8.91	9.72	8.77	9.32	8.83	8.34	7.55
1961	7.97	8.45	6.73	8.32	8.33	6.85	8.63	9.58	9.47	9.29	8.73	7.65
1962	7.25	7.90	6.99	8.29	9.15	8.52	9.54	10.14	9.00	8.07	7.70	7.44
1963	7.31	8.25	7.14	8.17	8.15	8.55	8.96	8.65	8.80	10.16	8.49	7.38
1964	7.31	7.29	7.00	7.71	8.06	8.10	9.32	10.46	9.63	8.85	8.86	7.42
1965	7.30	7.59	6.92	7.53	9.58	8.22	9.61	9.27	8.10	8.87	8.94	8.07
1966	6.81	7.38	6.94	7.71	7.58	8.21	12.61	8.99	8.49	9.45	8.33	7.50
1967	7.04	7.36	6.86	7.74	7.32	7.35	8.61	10.16	10.66	9.41	9.09	8.38
1968	7.39	7.66	7.41	7.83	8.33	8.11	9.75	8.81	9.58	8.95	8.75	7.44
1969	7.24	7.76	7.40	8.16	8.51	8.45	9.26	9.32	8.53	8.57	8.81	8.00
1970	7.08	7.78	7.30	7.82	8.24	8.16	9.68	9.58	9.85	8.49	8.26	7.77
1971	6.82	8.08	7.09	8.14	8.32	8.24	10.41	9.54	9.97	8.21	7.97	7.21
1972	6.16	7.73	7.89	7.62	7.96	9.53	9.99	9.52	9.03	8.49	8.37	7.72
1973	8.26	7.64	8.03	7.63	7.75	7.99	9.59	9.76	9.56	8.15	8.52	7.13
1974	8.00	7.12	7.59	7.64	7.62	7.76	10.84	10.62	9.19	7.95	8.31	7.37
1975	7.09	7.47	7.80	6.76	7.48	8.32	10.01	9.63	9.53	9.05	8.55	8.31
1976	7.51	7.46	7.88	7.40	7.56	7.99	8.86	9.04	10.16	9.23	8.75	8.15
1977	8.91	9.08	8.26	8.06	8.59	8.82	7.85	8.69	8.48	7.74	8.30	7.21
1978	7.42	7.47	7.38	8.32	7.67	8.15	9.58	8.36	10.15	8.81	8.65	8.03
1979	7.67	7.48	8.40	7.47	8.85	7.75	8.54	8.96	8.92	9.19	8.11	8.65
1980	7.60	7.29	7.66	7.54	7.37	8.00	11.02	9.96	8.93	9.11	8.03	7.49
1981	7.92	7.58	8.52	7.43	8.77	8.43	8.47	7.83	9.37	8.74	8.22	8.70
1982	7.40	8.80	7.64	7.52	8.39	8.16	7.89	9.57	10.24	8.21	8.78	7.39
1983	7.35	7.32	7.83	6.97	7.99	7.82	9.68	12.25	9.26	8.30	7.63	7.61
1984	8.41	7.56	8.18	7.92	8.24	8.19	9.08	10.26	9.15	8.10	7.64	7.28
1985	7.78	7.41	7.73	8.17	8.04	7.16	10.41	8.74	9.94	9.09	7.76	7.76
1986	7.57	7.10	8.06	7.92	7.99	8.50	9.77	9.25	9.78	8.68	7.41	7.97
1987	7.03	7.50	8.44	8.16	7.47	9.31	9.00	9.75	9.33	8.39	8.11	7.50
1988	7.19	8.02	7.78	7.67	9.71	10.73	7.83	9.73	8.59	8.27	7.38	7.10
1989	7.66	6.81	7.56	7.30	9.09	7.93	9.55	9.57	8.57	9.57	8.24	8.15
1990	8.67	7.10	8.61	7.75	7.99	8.52	8.67	9.25	9.57	8.61	7.49	7.78
AVERAGE												
MONTHLY	7.43	7.64	7.71	7.74	8.18	8.35	9.40	9.52	9.36	8.70	8.23	7.74
PERCENTAGE												

Table 33: Monthly percentage of total yearly water use, 1957-1991, City of Rolla.

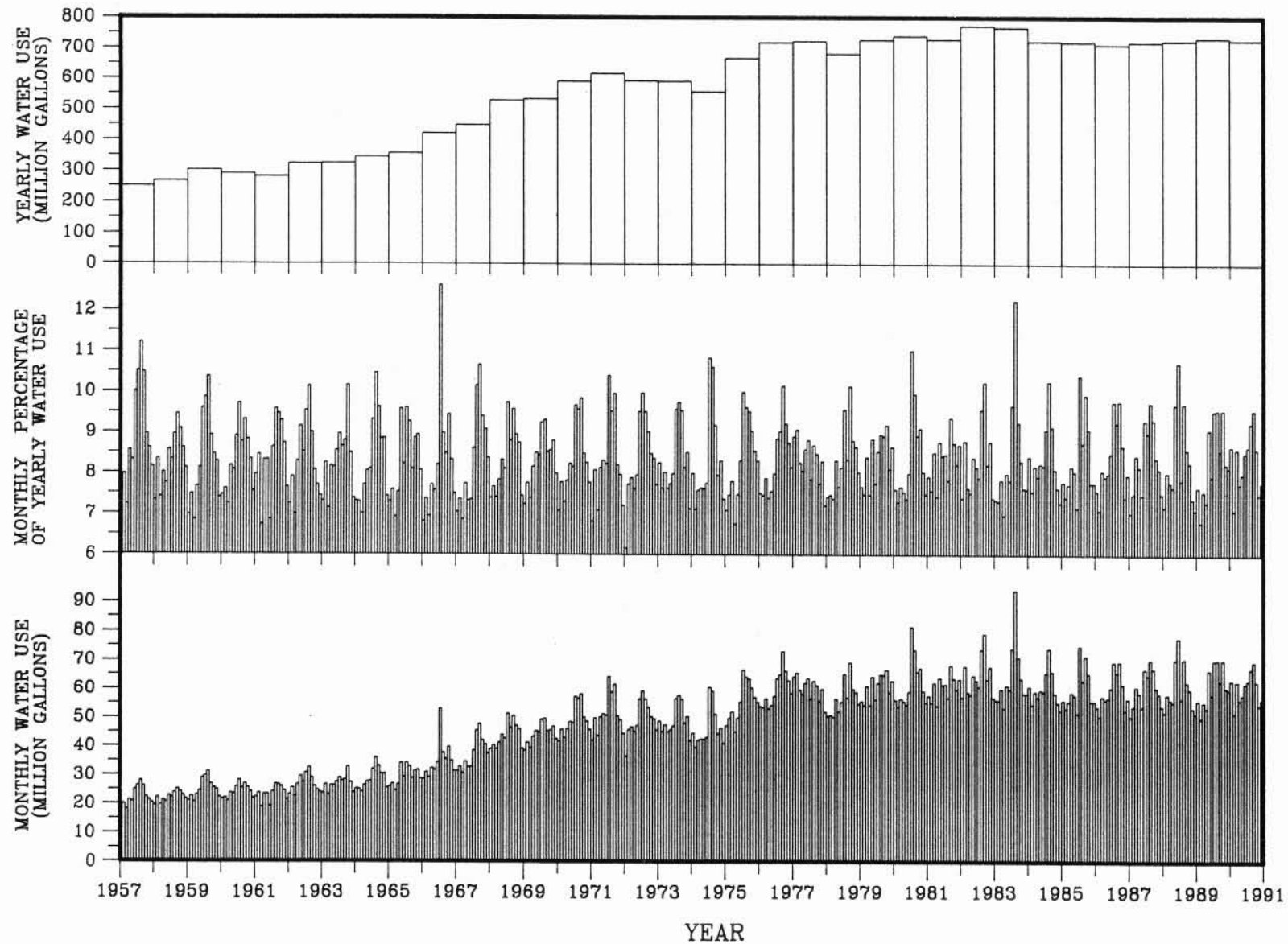


Figure 6: Monthly and yearly water production, City of Rolla.

YEARLY PRODUCTION (MILLION GALLONS)

Year	Rolla	St. James	Phelps Co. PWSD #2
1945	119.98		
1946	135.92		
1947	154.98		
1948	164.68		
1949	170.12		
1950	177.67		
1951	194.64		
1952	214.44		
1953	230.57		
1954	246.93		
1955	233.14		
1956	243.97		
1957	249.66		
1958	266.37		
1959	301.93		
1960	290.25		
1961	280.92		
1962	323.19	68.89	
1963	323.92	48.48	
1964	344.88	84.48	
1965	356.72	74.37	
1966	421.13	93.20	
1967	449.02	107.05	
1968	528.58	83.05	
1969	534.23	94.19	
1970	591.71	94.68	
1971	618.71	110.47	
1972	594.68	104.00	
1973	592.92	109.07	
1974	559.74	114.50	
1975	668.57	113.72	
1976	720.79	123.40	
1977	724.80	129.21	
1978	683.90	132.64	
1979	729.28	133.83	
1980	741.67	150.00	
1981	730.83	137.44	
1982	774.49	126.73	28.19
1983	768.91	133.71	31.11
1984	724.93	142.70	30.69
1985	722.44	141.07	35.16
1986	714.30	133.90	35.12
1987	723.04	136.86	37.57
1988	727.35	144.96	41.63
1989	735.81	134.14	42.24
1990	729.53	128.19	39.88
Total	21,536.24	3,328.93	321.59

Table 34: Yearly water production for Rolla, St. James, and Phelps County PWSD #2.

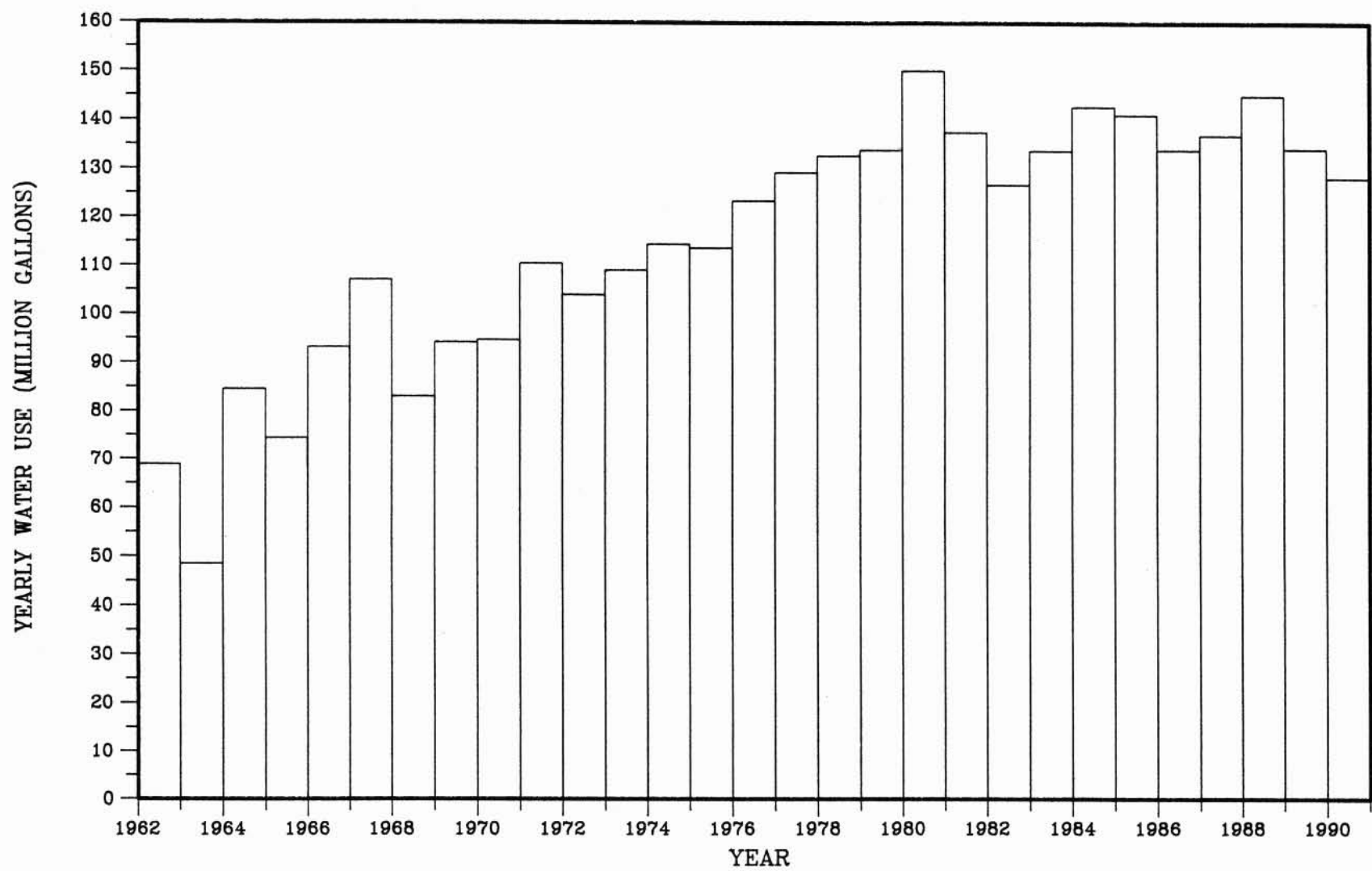


Figure 7: Yearly water production: City of St. James

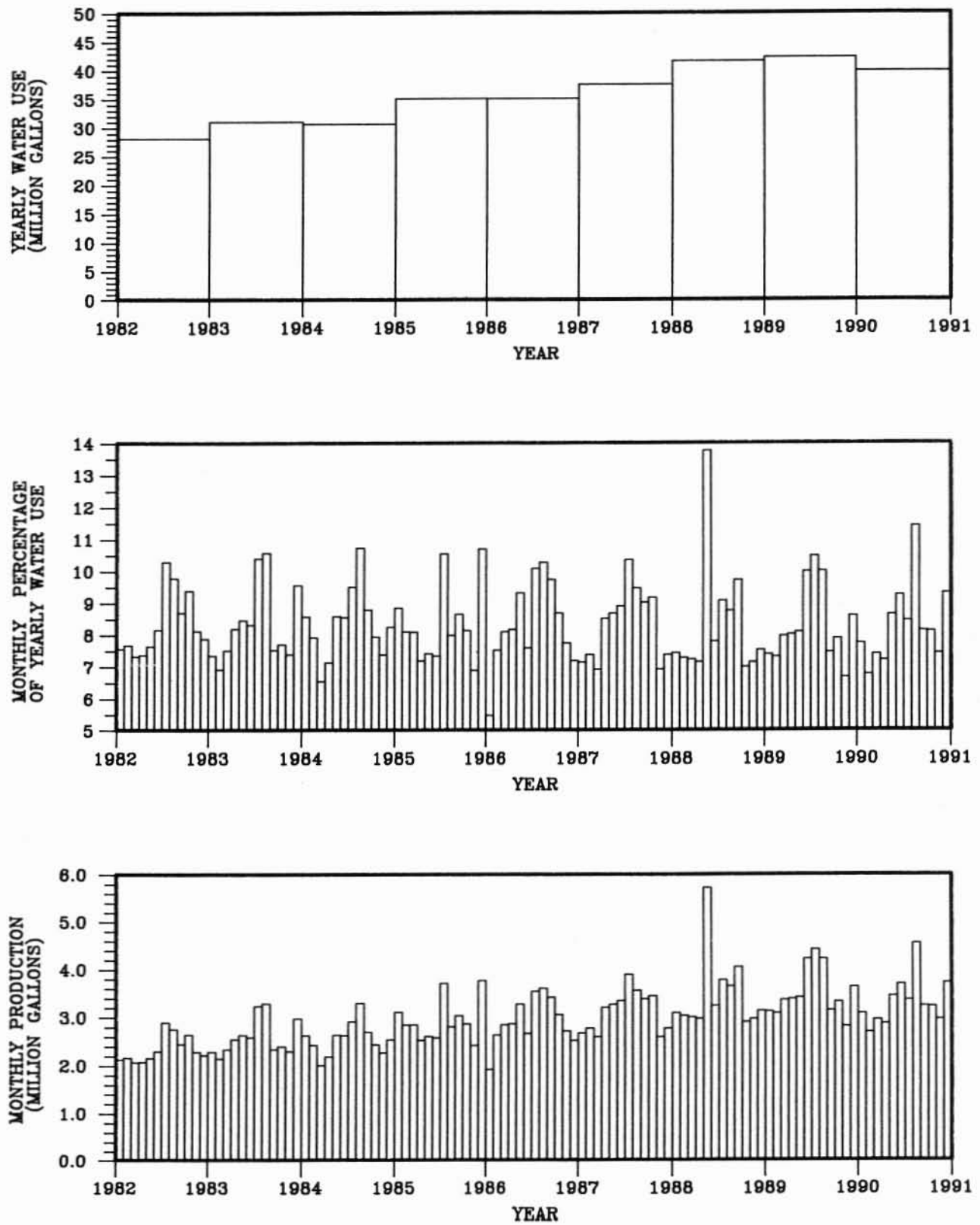


Figure 8: Monthly and yearly production, Phelps County PWSD #2.

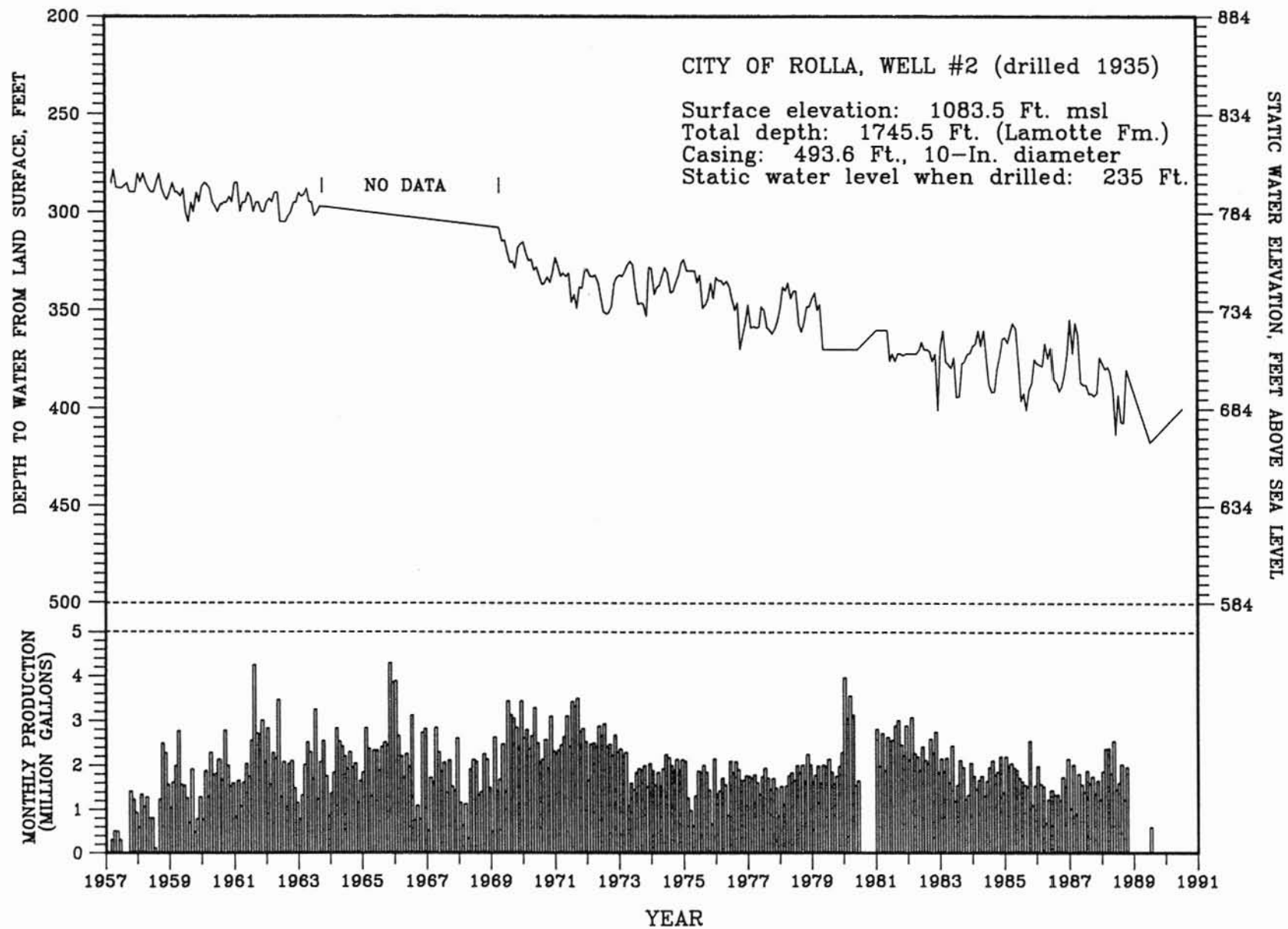


Figure 9: Water-level changes and monthly production, 1957-1990, City of Rolla well #2.

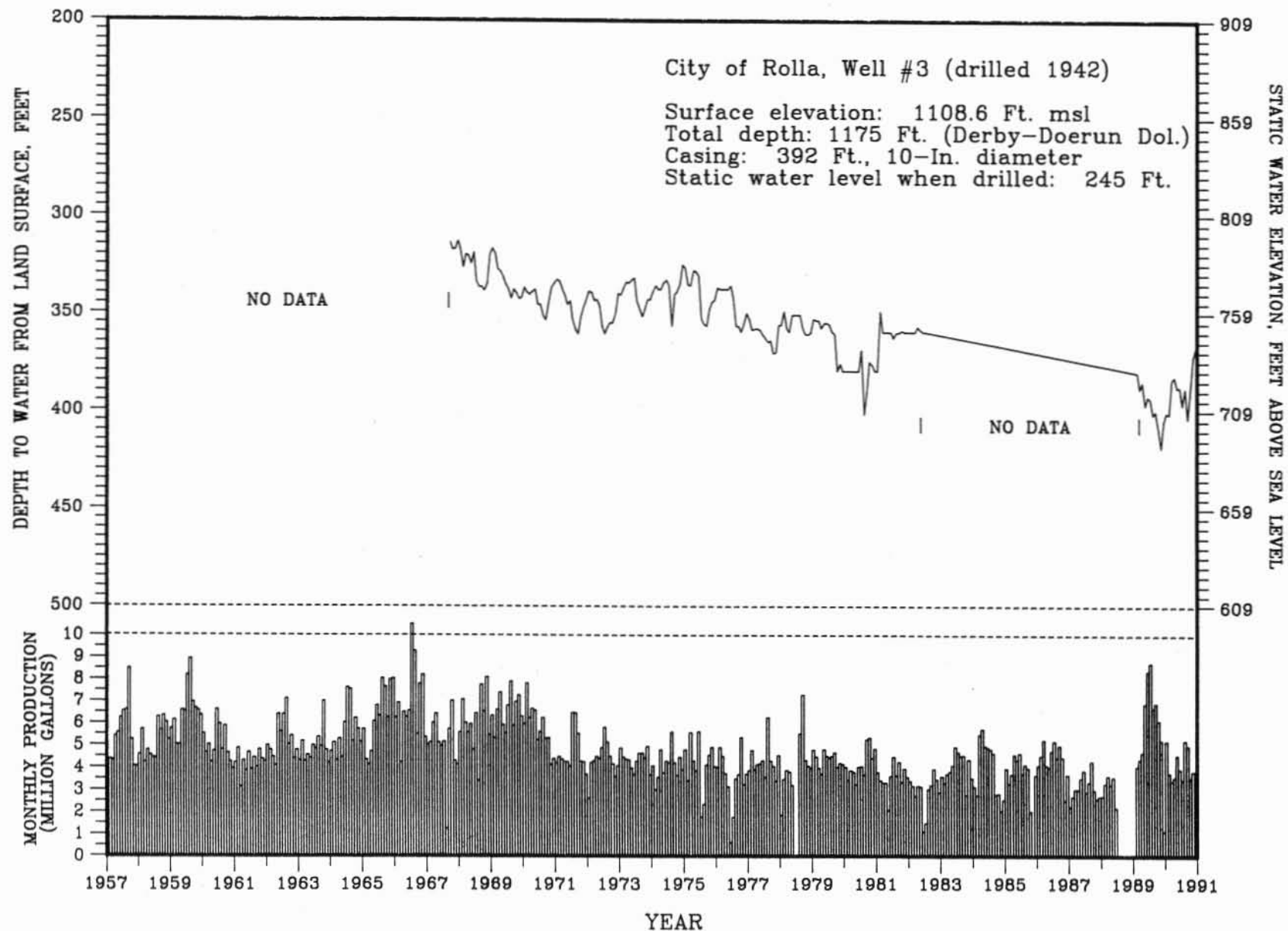


Figure 10: Water-level changes and monthly production, 1957-1991, City of Rolla well #3.

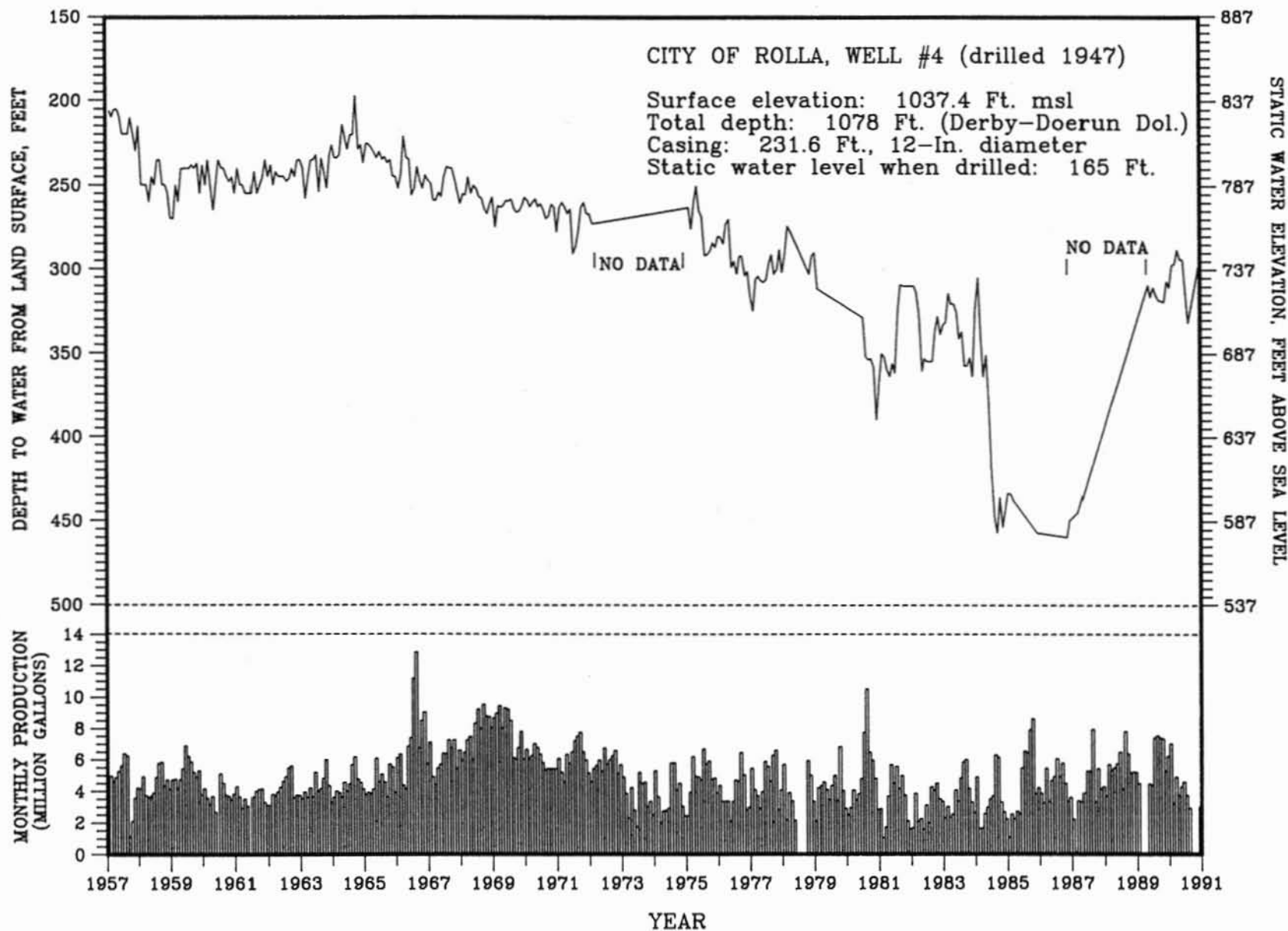


Figure 11: Water-level changes and monthly production, 1957-1991, City of Rolla well #4.

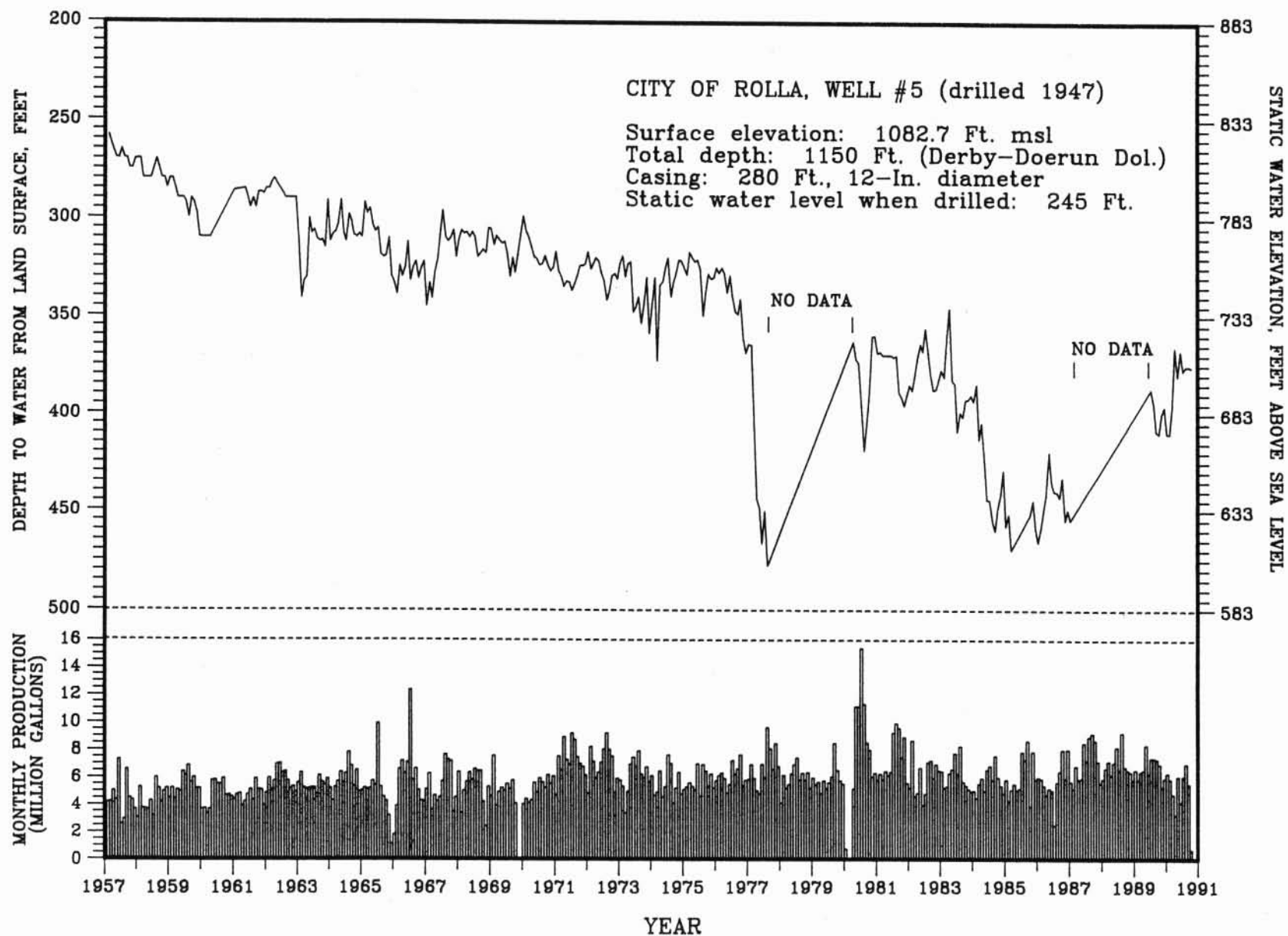


Figure 12: Water-level changes and monthly production, 1957-1991, City of Rolla well #5

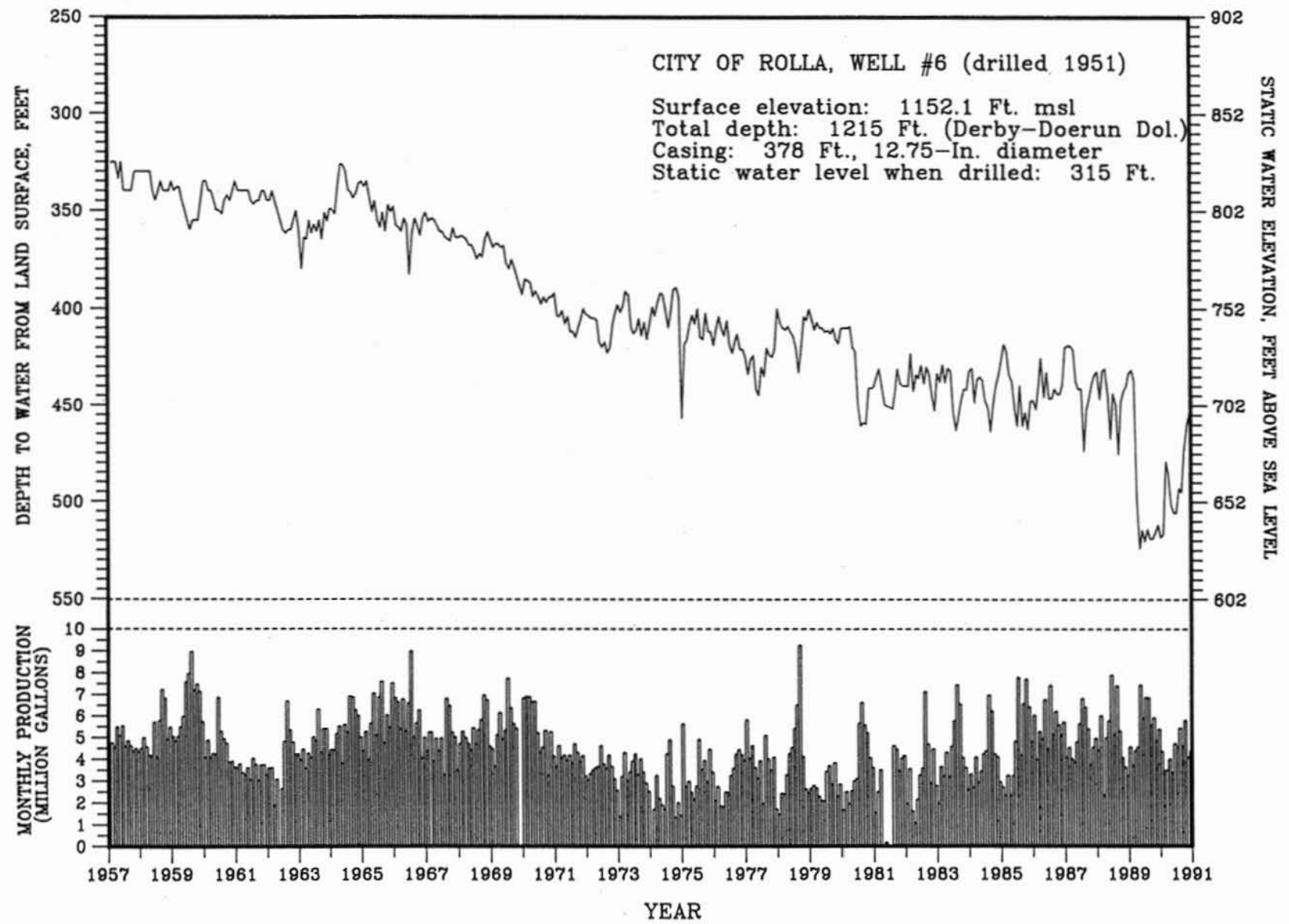


Figure 13: Water-level changes and monthly production, 1957-1991, City of Rolla well #6.

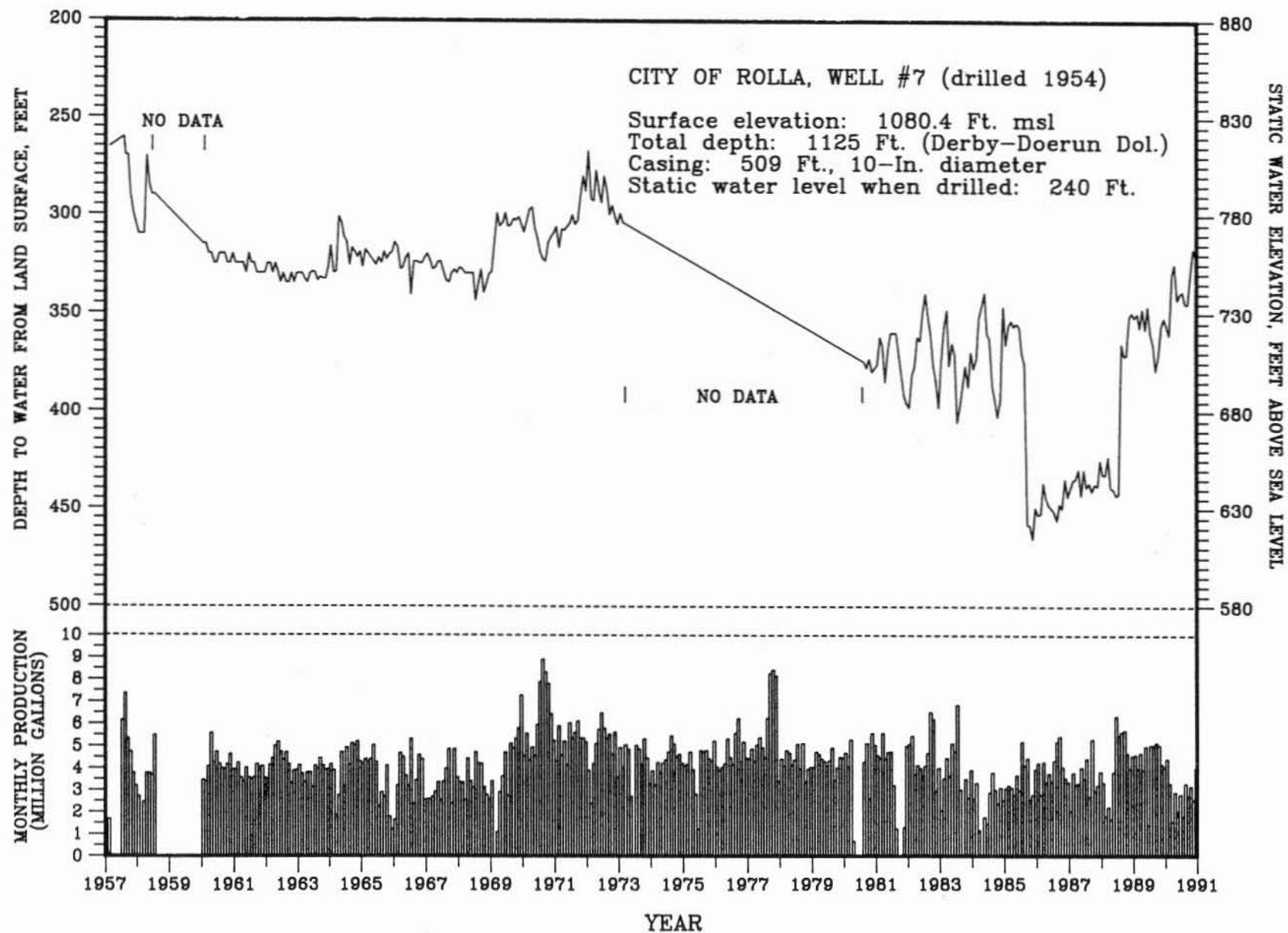


Figure 14: Water-level changes and monthly production, 1957-1991, City of Rolla well #7.

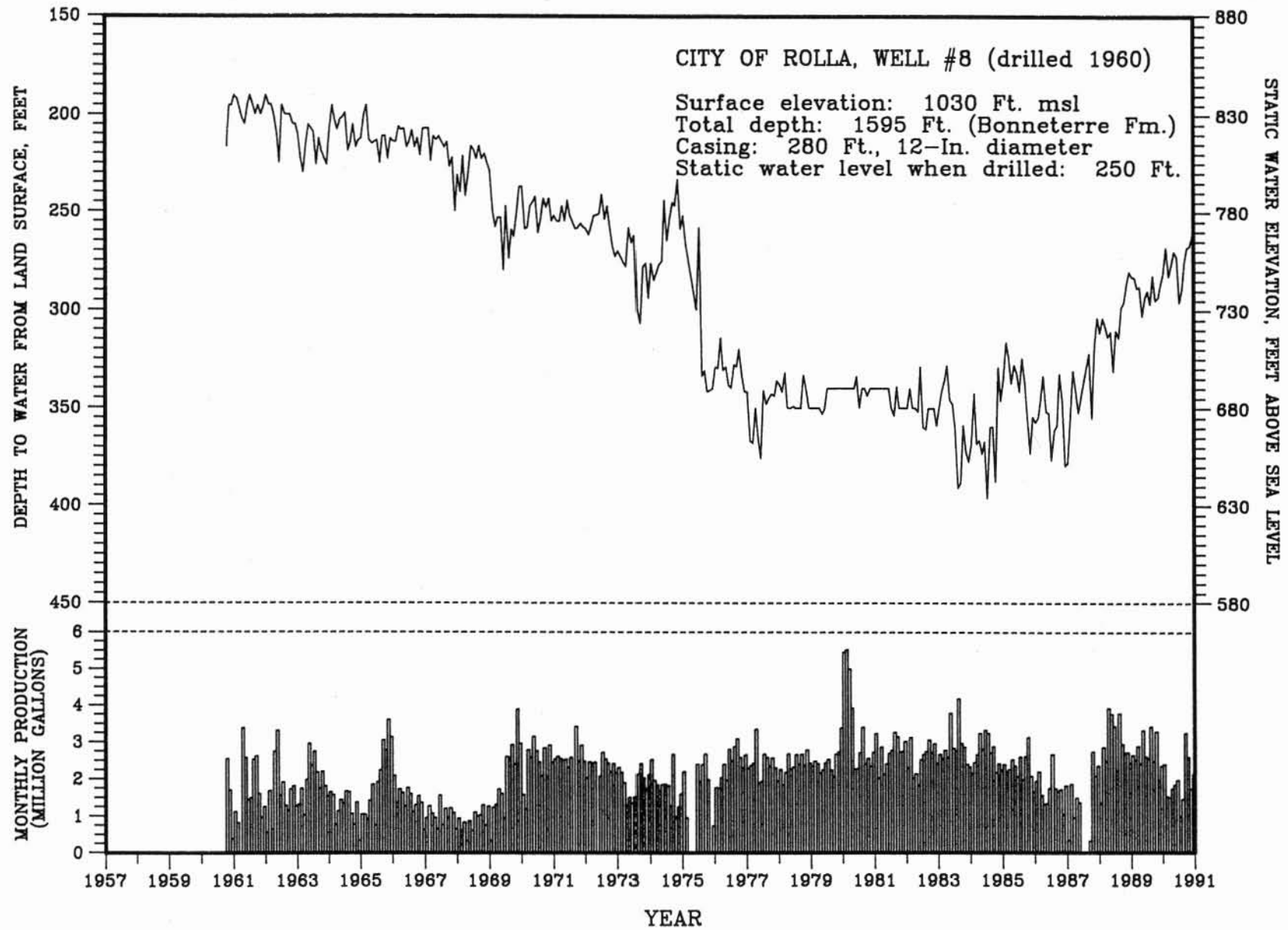


Figure 15: Water-level changes and monthly production, 1957-1991, City of Rolla well #8.

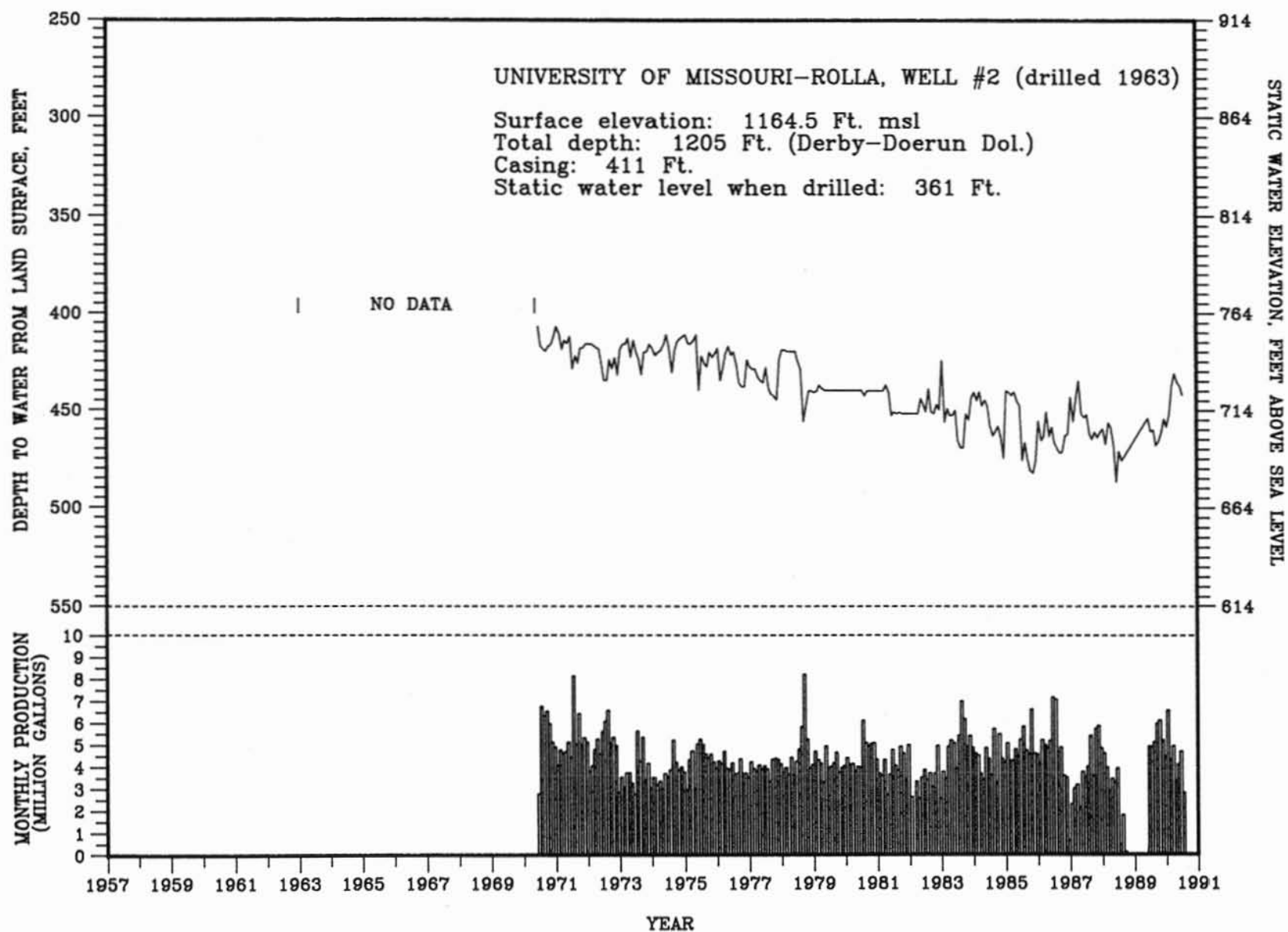


Figure 16: Water-level changes and monthly production, 1957-1991, UMR well #2.

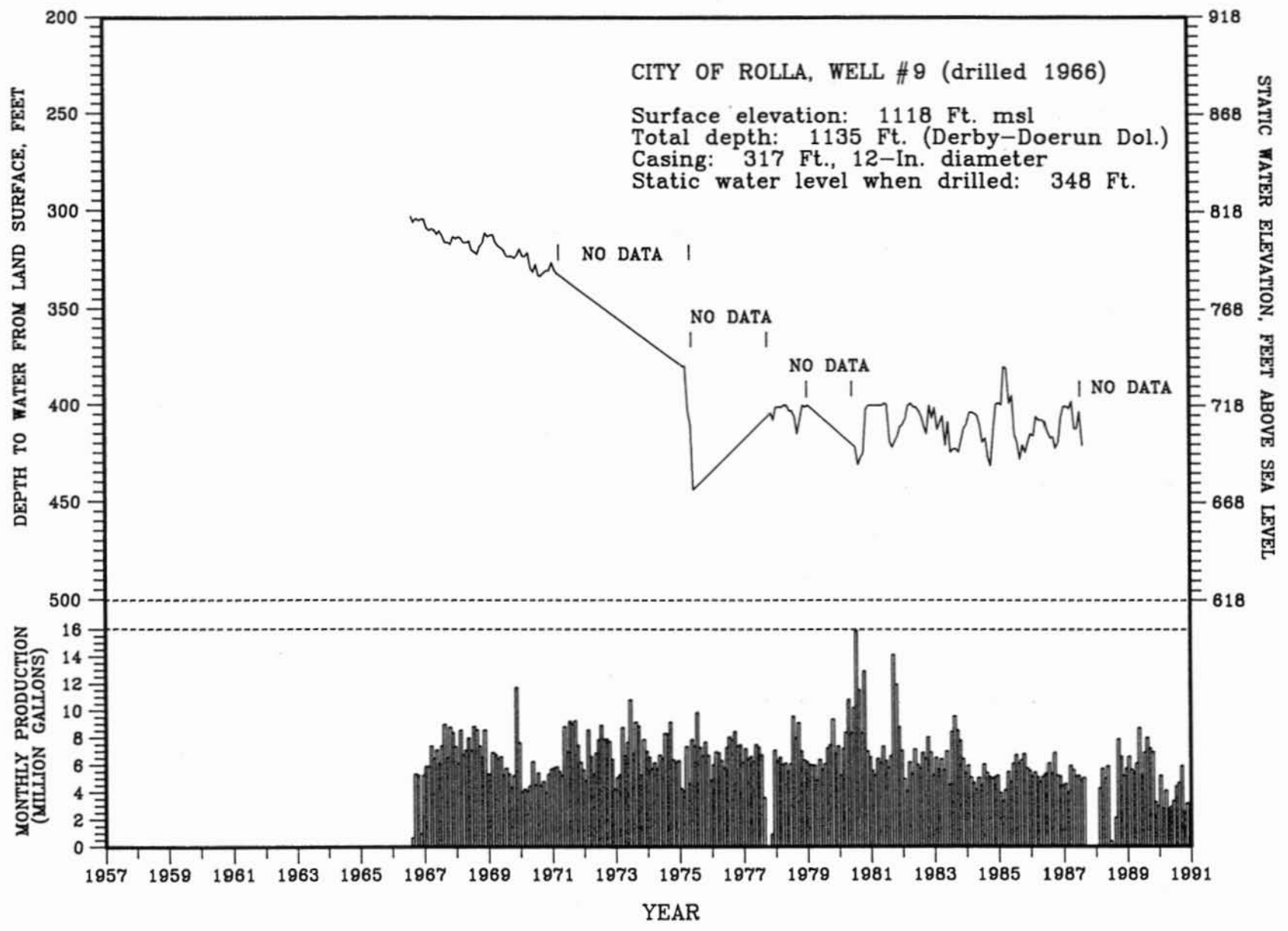


Figure 17: Water-level changes and monthly production, 1957-1991, City of Rolla well #9.

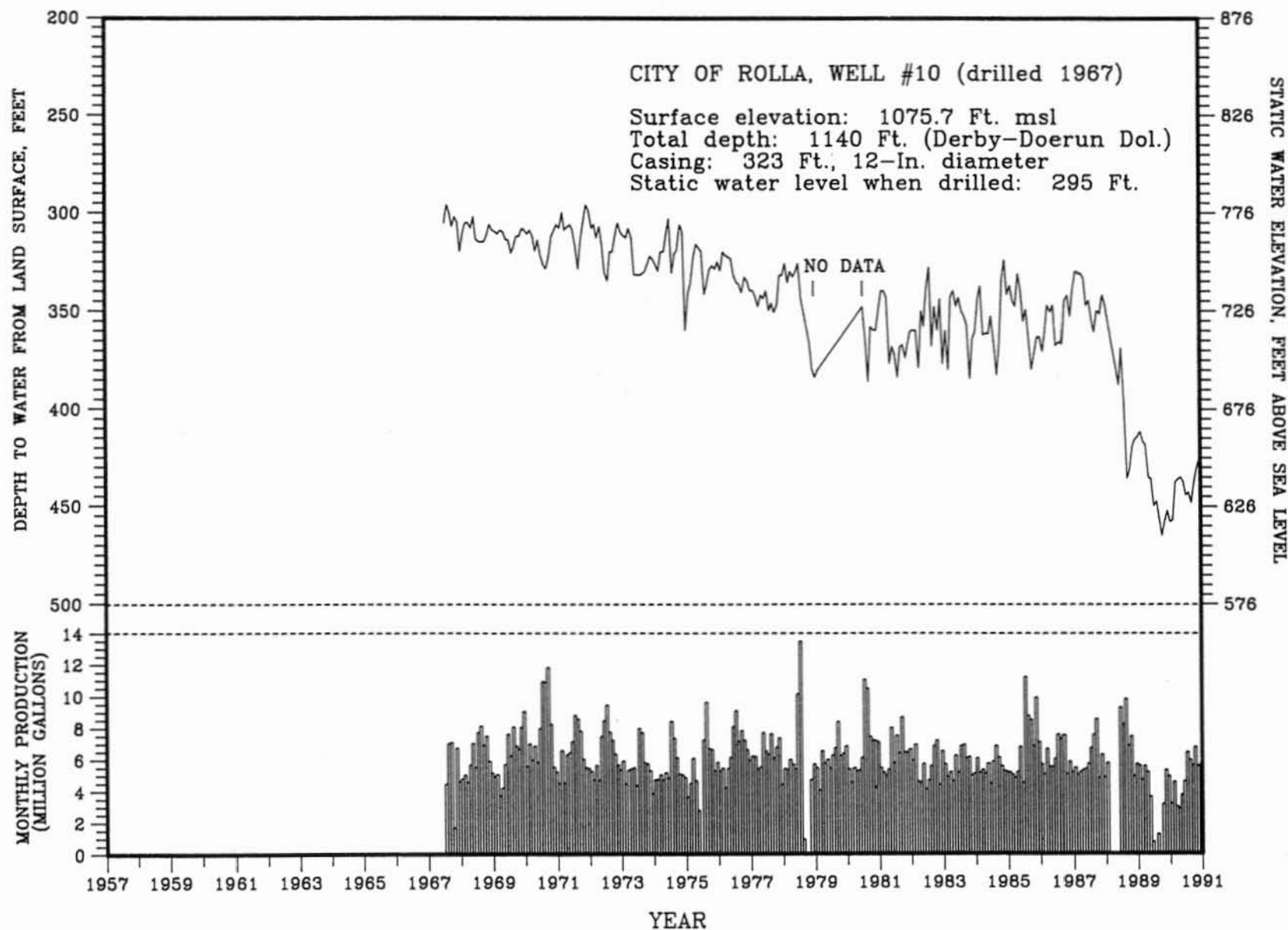


Figure 18: Water-level changes and monthly production, 1957-1991, City of Rolla well #10.

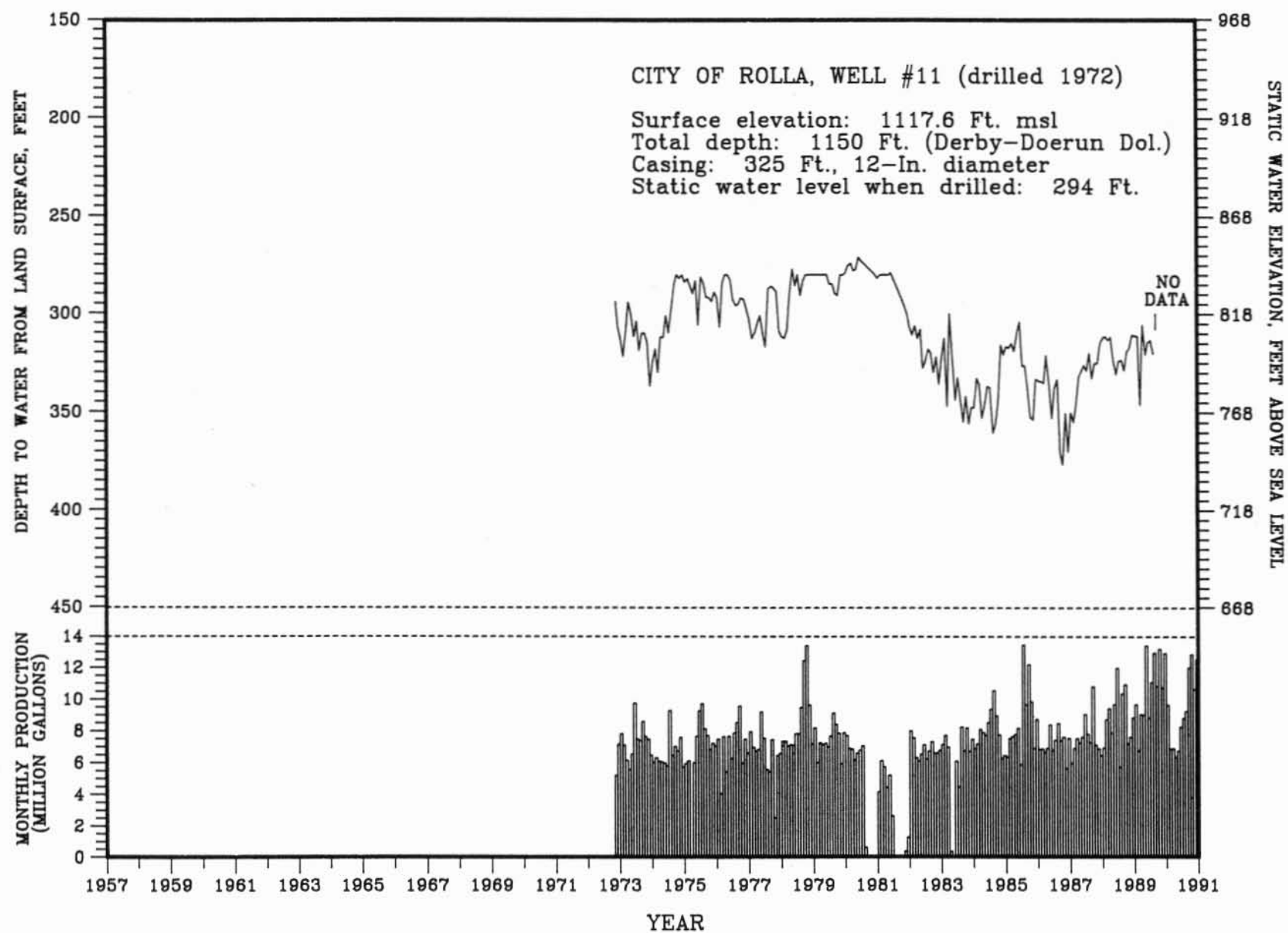


Figure 19: Water-level changes and monthly production, 1957-1991, City of Rolla well #11.

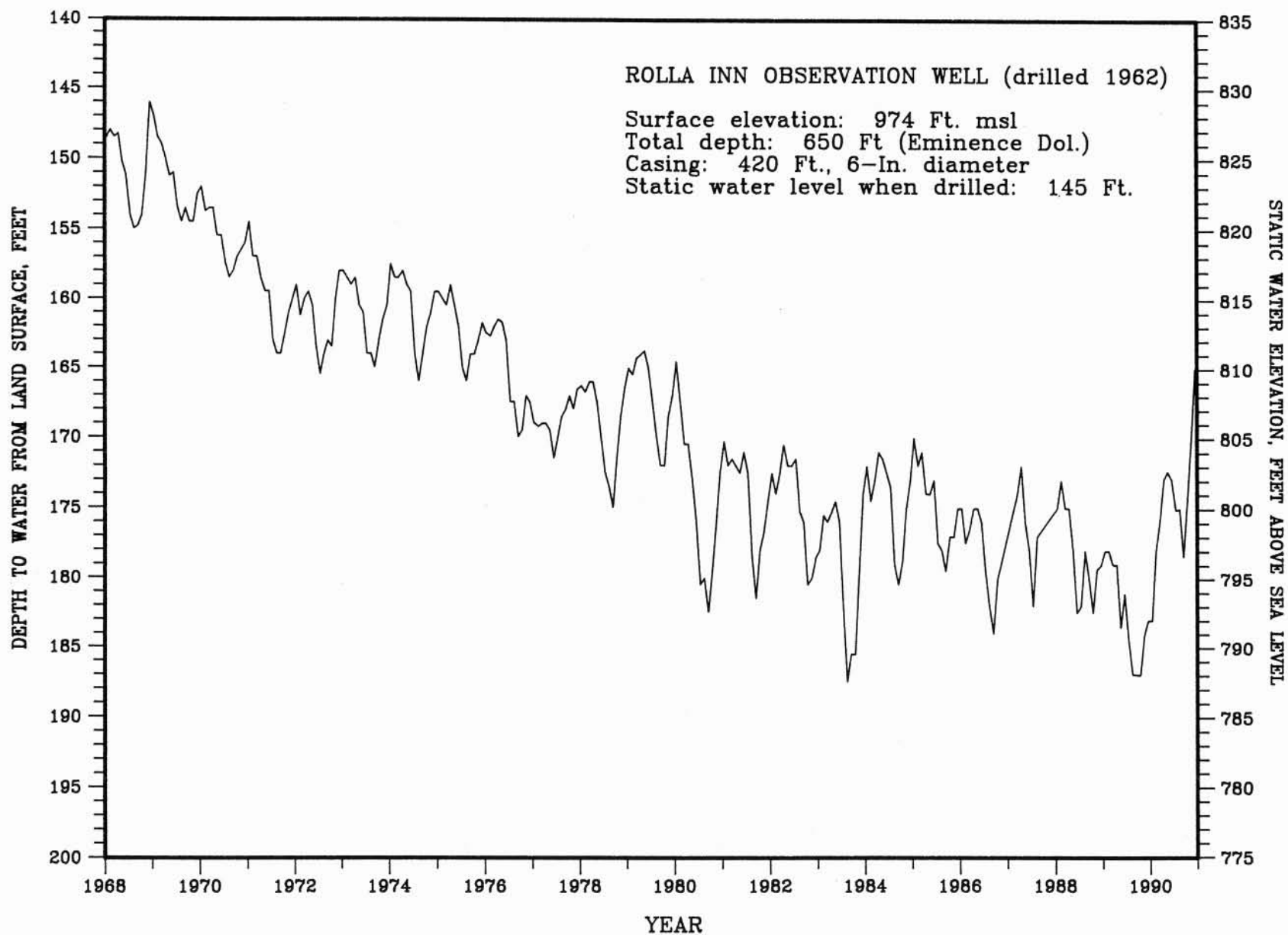


Figure 20: Hydrograph, 1969-1991, Rolla Inn observation well.

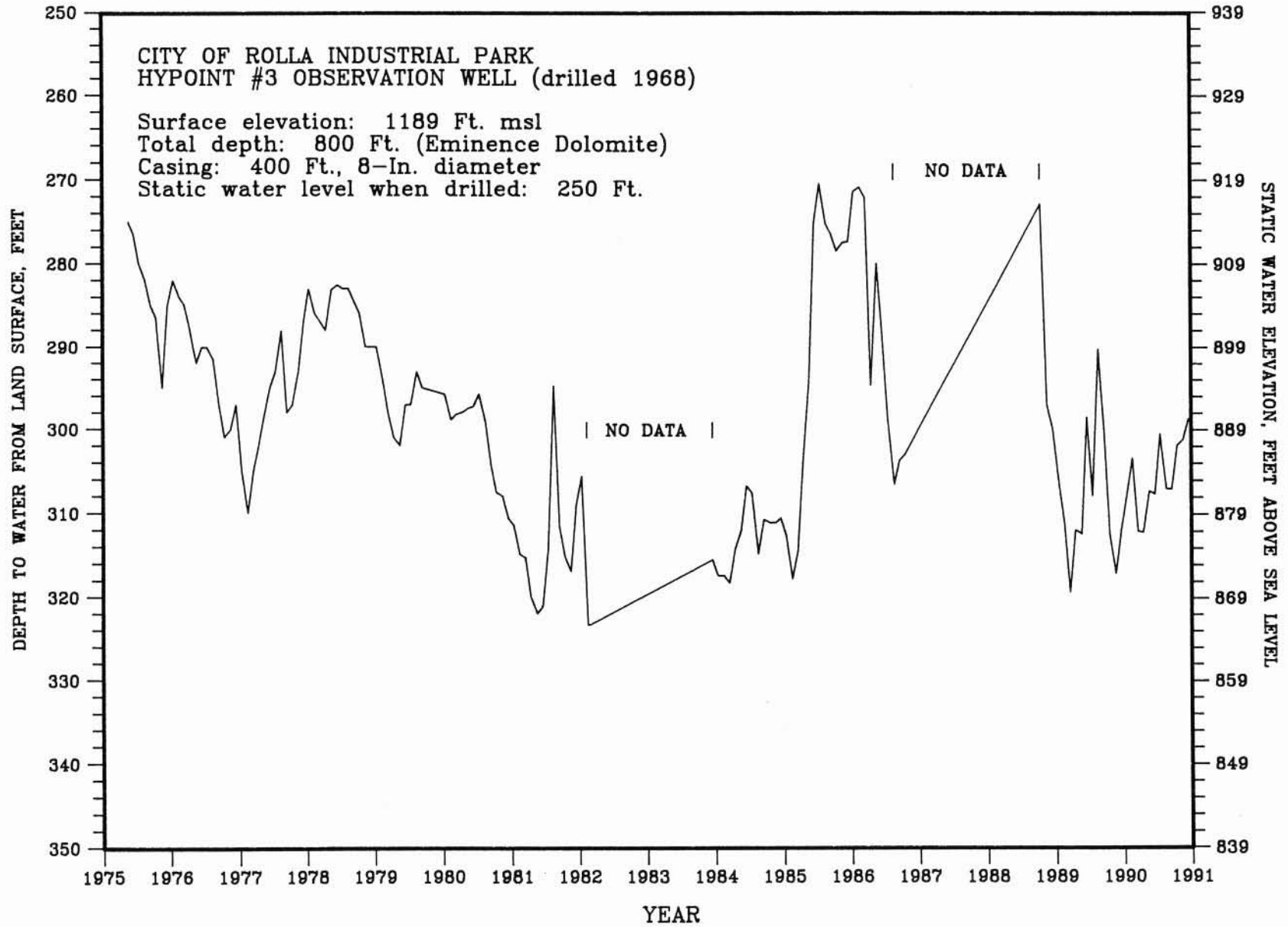


Figure 21: Hydrograph, 1975-1991, Hypoint #3 observation well.

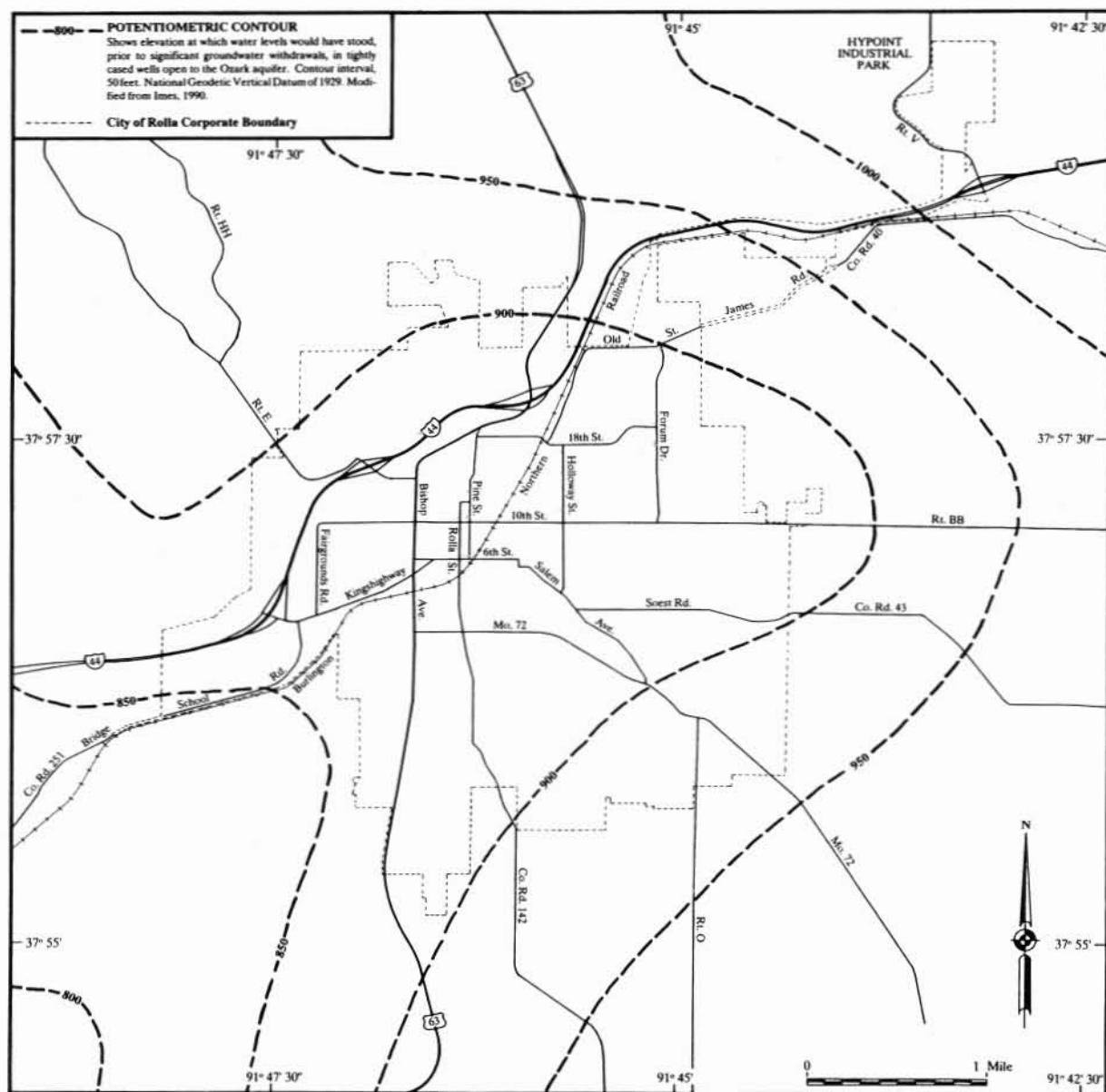


Figure 22: Predevelopment potentiometric map of the Ozark aquifer (after Imes, 1990).

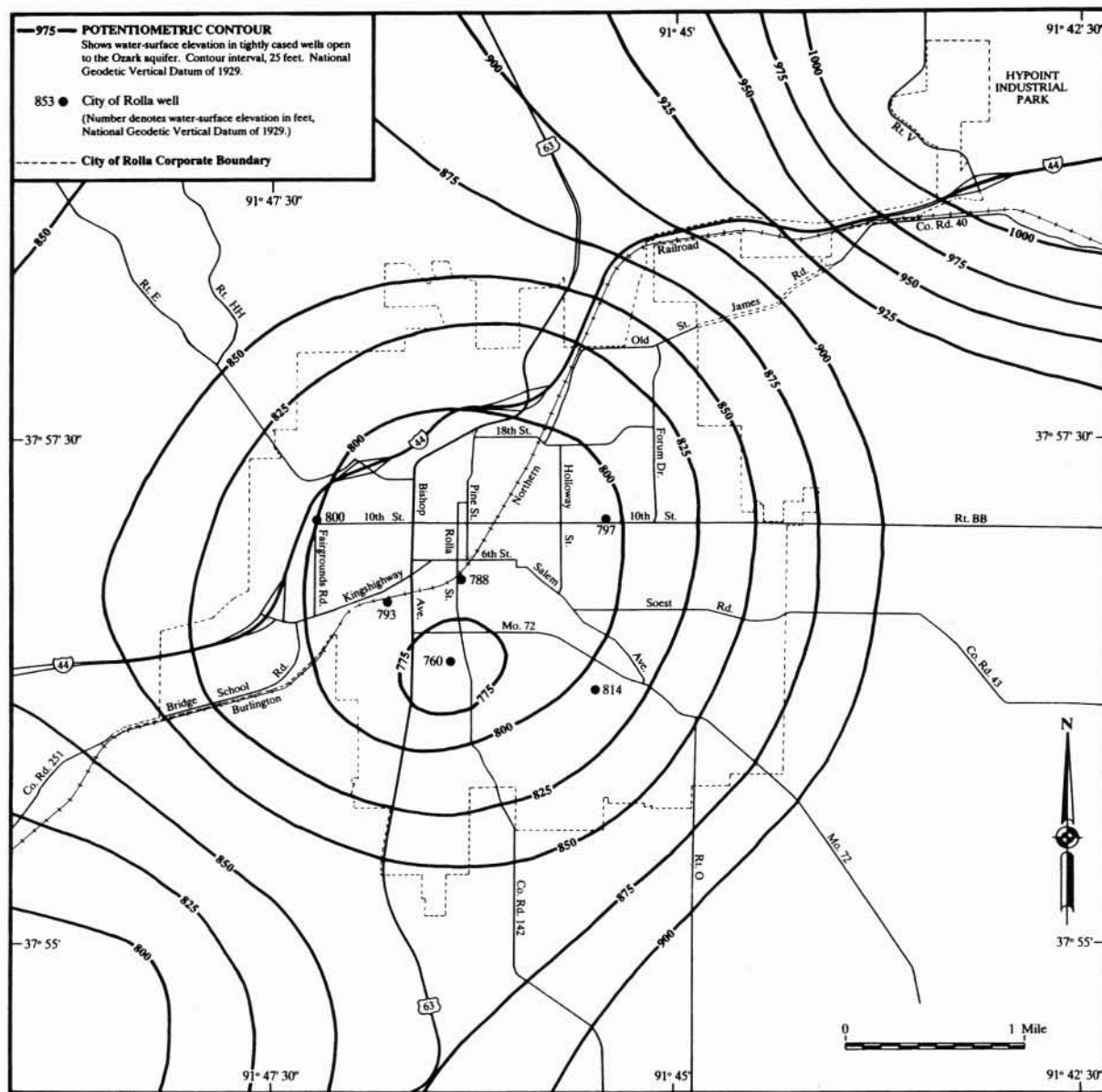


Figure 23: Potentiometric map of the Ozark aquifer, August, 1960.

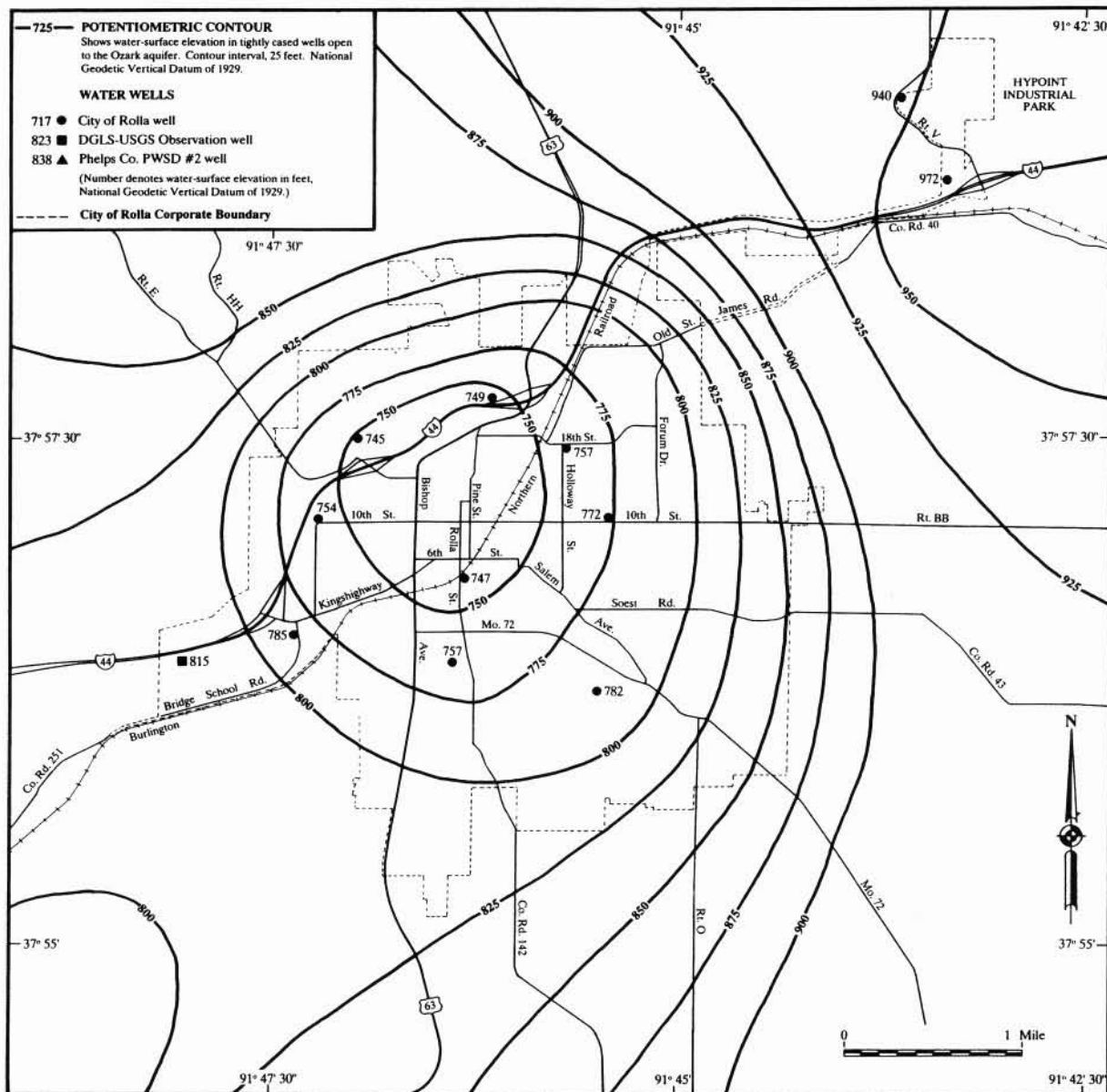


Figure 24: Potentiometric map of the Ozark aquifer, August, 1970.

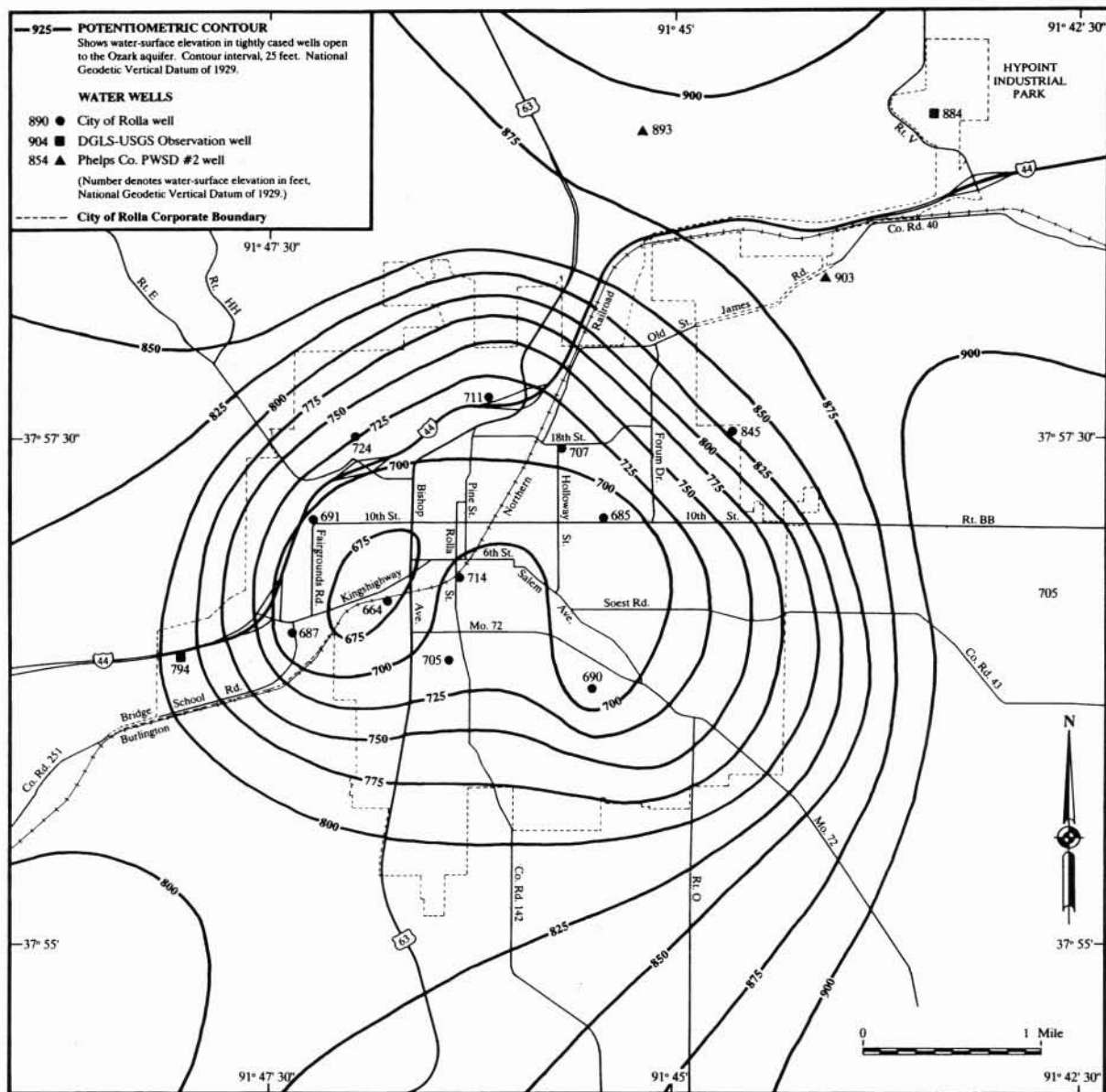


Figure 25: Potentiometric map of the Ozark aquifer, August, 1980.

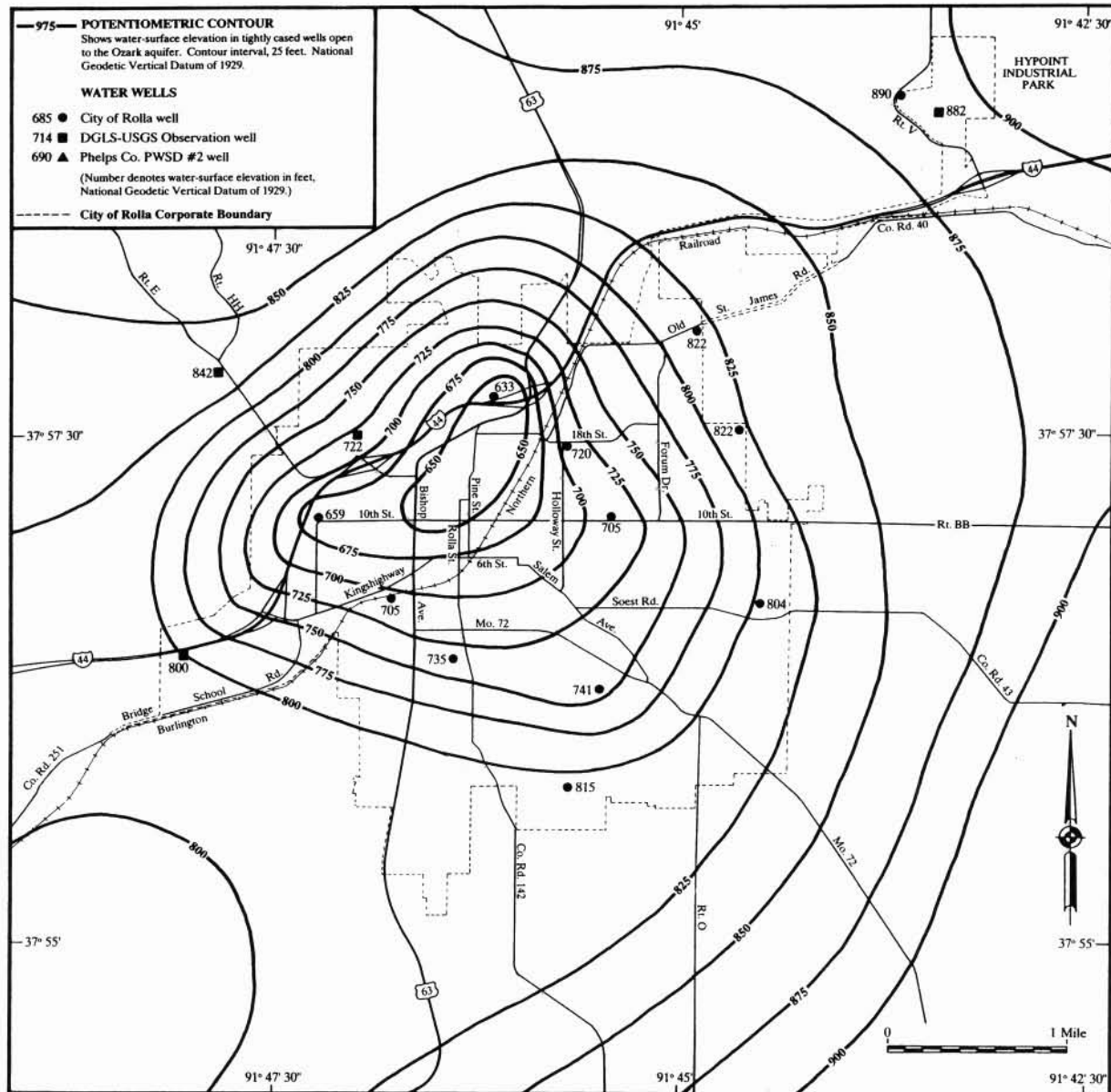


Figure 26: Potentiometric map of the Ozark aquifer, August, 1990.

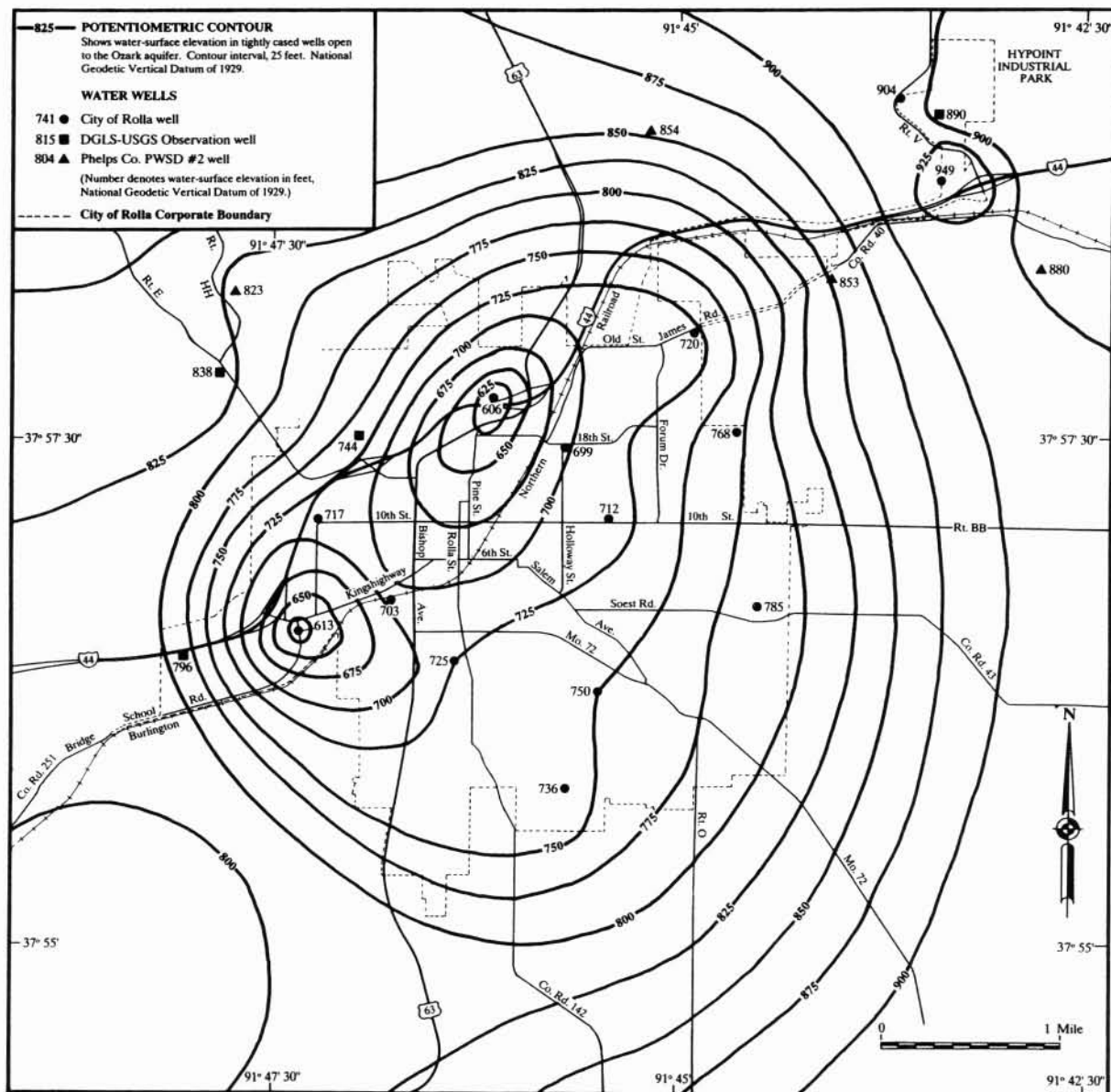


Figure 27: Potentiometric map of the Ozark aquifer, August, 1992.

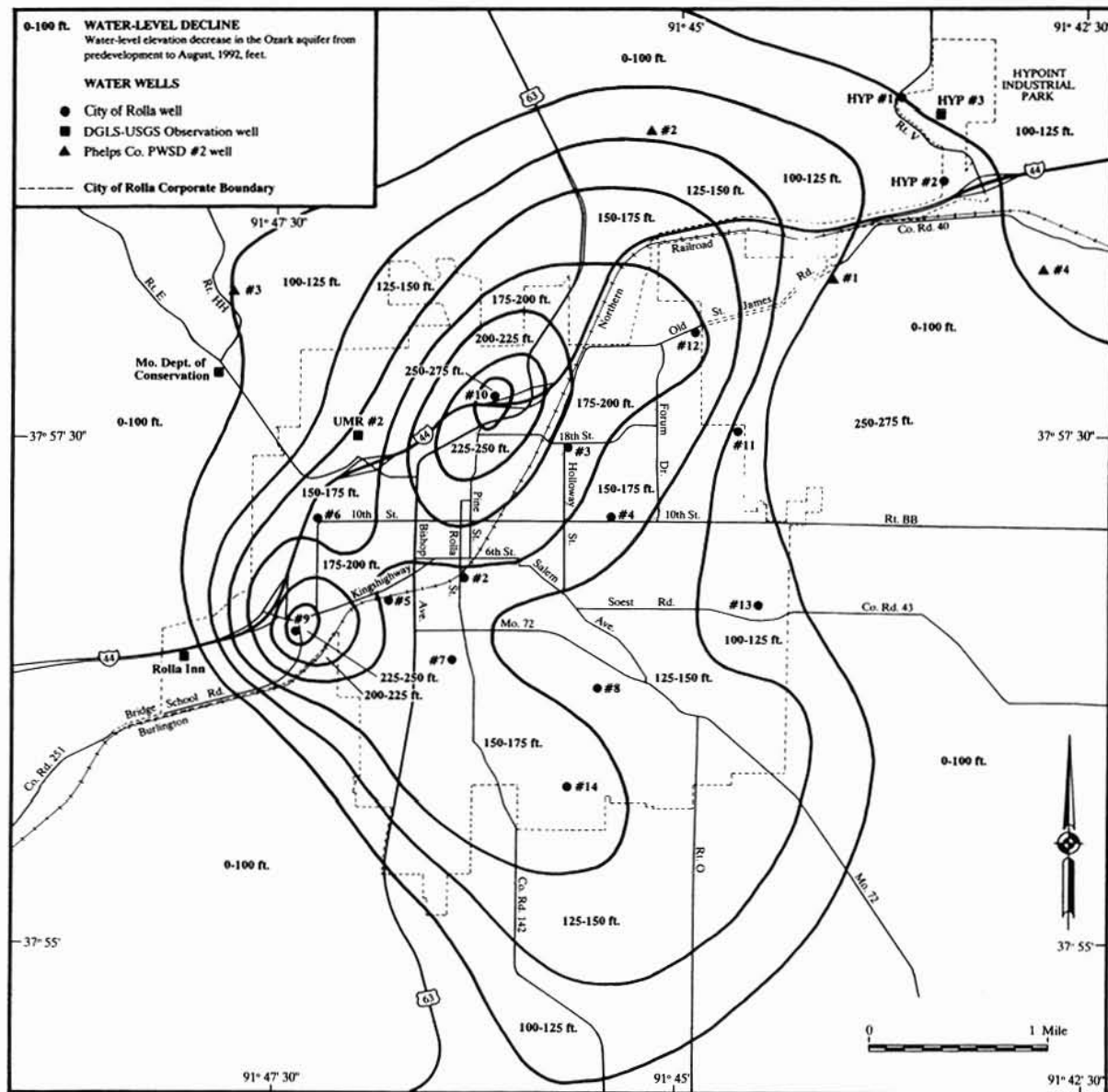


Figure 28: Water-level decline in the Ozark aquifer from predevelopment to 1992.

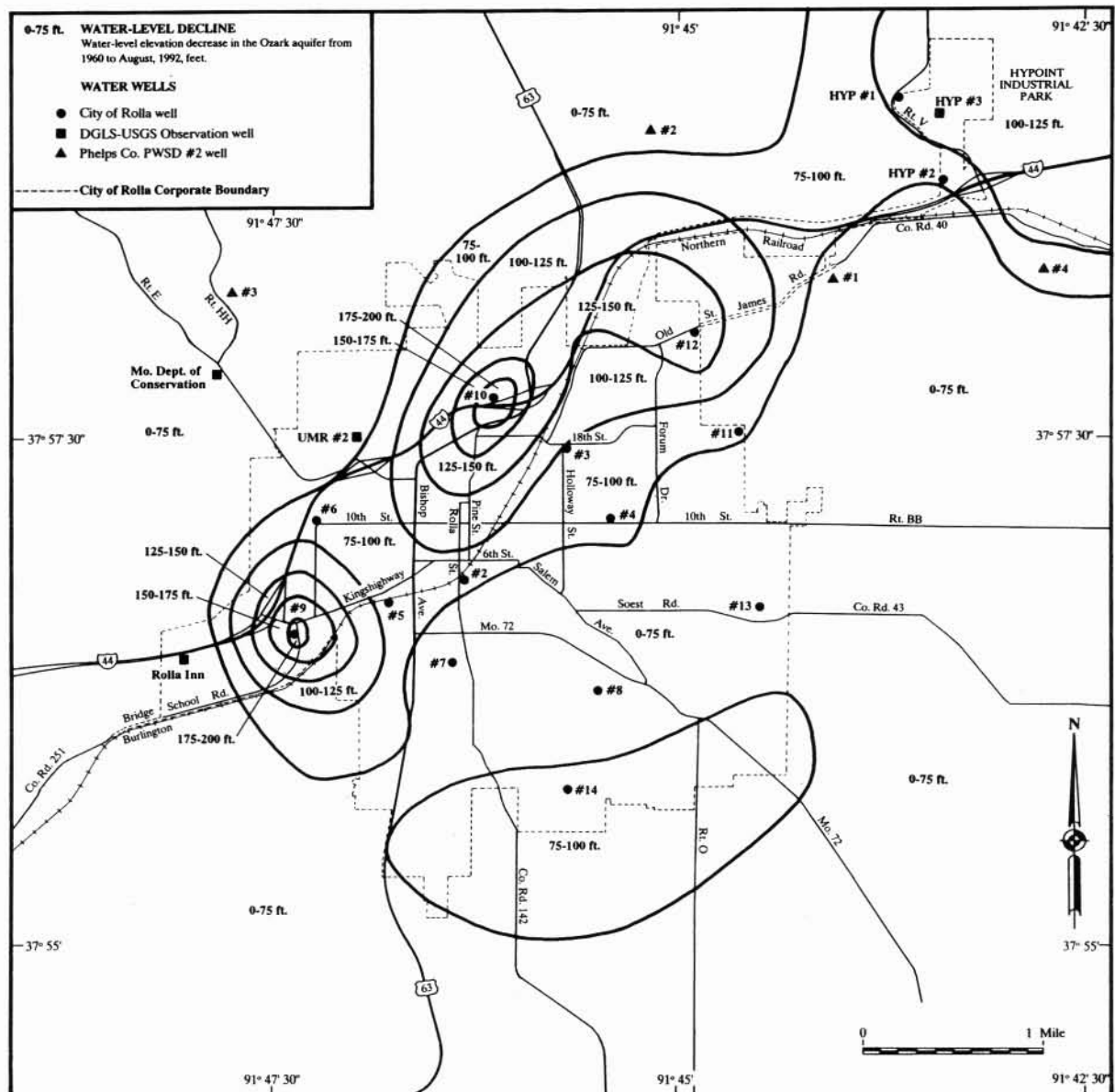


Figure 29: Water-level decline in the Ozark aquifer between 1960 and 1992.

Water-level hydrographs were prepared for 10 City of Rolla wells, including UMR well #2, which showed a gradual but relatively steady groundwater-level decline in the Ozark aquifer at Rolla. The wells showed from less than 1 ft/year to more than 7.7 ft/year water-level decline, and averaged about 3.0 ft/year.

Potentiometric maps constructed for each 10-year period beginning 1960, and also for August, 1992, showed drawdown in the Ozark aquifer to have increased each 10-year period. Two maps showing water-level decline in the Ozark aquifer were developed from potentiometric map data. The water-level decline map covering the predevelopment to 1992 period of time (figure 28) showed that water-level declines of 100 ft to 150 ft have occurred in a 17 mi² area in and adjacent to Rolla. Water-level declines of between 150 ft and 200 ft have occurred in a 6.1 mi² area, and in excess of 200 ft in a 1 mi² area. This map was developed by contouring the difference between the August, 1992, potentiometric surface and the predevelopment potentiometric surface. Based on this map, water-level declines in and near Rolla show that about 82.3 billion ft³ of aquifer has been dewatered. However, assuming a specific yield of 0.1, this volume of saturated rock would produce about 62 billion gallons of water, about twice the estimated volume produced.

The water-level decline map for the period between August, 1960, and August, 1992 (figure 29), probably more accurately portrays the magnitude of water-level changes in the Ozark aquifer. Based on this map, water-level decline since 1960 has been 75 ft to 100 ft within a 10.1 mi² area in and near Rolla, and 100 ft to 150 ft within a 4.5 mi² area of Rolla. Water-level decline of more than 150 ft has occurred within a very limited area, 0.3 mi². Based on this map, about 29 billion ft³ of aquifer has been dewatered. Assuming a specific yield of 0.1, this volume of aquifer would produce 21.7 billion gallons.

Support for the 1960-1992 water-level decline map being more representative of water-level changes is found in the water use information. Rolla and rural Rolla water use for the 60-year period between 1900 to 1960 is estimated to be 8 billion gallons. From 1960 to 1992, more than 3 times this volume of water, 24.5 billion gallons, was produced in slightly more than one-half the time. Because production from the Ozark aquifer was relatively low prior to 1960, water-level declines should also have been relatively small, and recharge from precipitation should have replenished most of the water produced from the aquifer. Also, the predevelopment to 1992 water-level decline map shows 3 times as much aquifer dewatered as did the 1960 to 1992 map, even though only one-fourth of the total water production occurred prior to 1960.

The Ozark aquifer has supplied water to nearly every resident, business, farm, and industry in the Rolla area for nearly a century, and will likely continue to be the major water-supply source for many years. A important question is whether the aquifer is capable of continuing to supply the needed volume of water, or is present water use exceeding the safe yield of the aquifer. The safe yield of an aquifer, which is the amount of water that can be produced without causing undesired effects such as excessive water-level declines, is a function of several factors including aquifer characteristics, aquifer recharge, and rate of groundwater movement in the aquifer. Recharge estimates for the Ozark aquifer are 2.3 in./year to 9.5 in./year, which equate to about 40 million gallons per square mile per year to 165 million gallons per square mile per year. Assuming 9.5 in. of recharge, the recharge entering the aquifer within an area of 6 mi² would provide 1 billion gallons per year, which is the current water use rate for Rolla and rural Rolla. An area of 25 mi² would be needed with a recharge rate of 2.3 in./year to supply 1 billion gallons per year.

The continuing water-level decline in the Ozark aquifer in the Rolla area shows that the aquifer is not under steady-state conditions; outflow from the aquifer is greater than inflow, resulting in lowering of water-level within the aquifer. It is difficult to predict the magnitude of future water-level changes. Such predictions depend on accurately forecasting population changes and changes in per capita water use. Assuming no increase in aquifer withdrawal rates, the cone of depression will continue to gradually expand until 1) recharge within the radius of influence equals the volume of water being produced from the aquifer, or 2) the volume of water moving into the cone of depression from up-gradient, plus recharge, is sufficient to replenish the volume of water produced.

Further water-level decline can hopefully be minimized by selectively pumping wells within Rolla where yields and specific capacities are highest, and where water-level decline has been the least. Water-level decline is greatest in the northern and western parts of the City in an area about 4 mi long and 1.5 mi to 2 mi wide, paralleling I-44 and the Burlington Northern Railroad. Water-level decline is the least in the northeast, east, and southeast parts of the City. Producing more water in these areas, including the Hypoint Industrial Park, while decreasing production from the wells in the area of greatest water-level decline, should help minimize additional drawdown.

The level of detail and quality of records kept by RMU have proven invaluable in analyzing the Ozark aquifer in the Rolla area. The data collected by the City primarily

consists of static water level before pumping begins, drawdown at the end of the pumping cycle, length of pumping cycle, volume of water pumped, and other information. The collection of this information will, undoubtedly, continue. Regular (at least monthly) static water level measurements should also be taken at any

inactive wells. Ideally, the information should be examined on a regular basis to see what changes have occurred in the aquifer, and to determine if modifications need to be made in operation of the water system to minimize the effects of pumping.

ACKNOWLEDGMENTS

This study was greatly helped by the efforts of several people. Cynthia Brookshire, DGLS, developed the computer data-storage system used by RMU for storing well production and water-level data. Susan Johnson, RMU, entered 34 years of monthly and daily water records for 15 wells into the computer data-storage system. John Twitty, General Manager of RMU when the project began, Dan Watkins, present RMU General Manager, and other staff members of RMU provided information

on operation of the water system, and assisted with this project in numerous ways. Appreciation is extended to Phelps County PWS #2, particularly Betty Harris for providing water-use information, and Ron Skyles for providing water-level measurements. Appreciation is also extended to St. James Municipal Utilities efforts in supplying historic water-use information for their city. Sharon Krause and Susan C. Dunn, DGLS, assisted in preparing this manuscript.

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THE HISTORY OF THE ELECTRIC AND WATER SYSTEMS IN ROLLA, MISSOURI

1880 TO 1975

AND OTHER WELLS IN AND AROUND ROLLA

by J.B. Bronson

**Prepared from old records and the stories of old residents, and early records of the
Missouri Geological Survey (Missouri Department of Natural Resources'
Division of Geology and Land Survey) and the files of the
Rolla Municipal Utilities which have accumulated since 1924.**

The American Utilities Company of Harrisburg, Pennsylvania, a holding company, purchased a number of electric and water properties in Missouri, Arkansas, and Kentucky from 1920 to 1926. They were small towns, not generally integrated and mostly in poor physical condition. In 1924, they purchased the Rolla electric and water system from Darlene Holcomb and her son-in-law George Silvers, and known as the Ozark Public Service Company. Mrs. Holcomb bought the electric and water system from the City of Rolla in 1918.

The operation of the electric and water systems by the City of Rolla from the first plant installed in the 1880s, until it was sold to Mrs. Holcomb in 1918, had been almost a complete failure. The management was under the Mayor and City Council with evidence of mismanagement and favoritism, so the City was very happy to sell the property to Mrs. Holcomb. She was a very aggressive and dynamic woman and while she had no previous utility experience she was determined to improve the service. This she did by converting the old 2 wire 120 volt DC electric system to AC, and extending the lines to more residences who could not be served by the DC lines. To accomplish this, she installed 3 Fairbanks Morse diesel oil engines and AC generators from 1919 to 1923. She installed an electric driven air compressor to pump water from the plant well into the water system. She shut down and removed the old boilers in the south side of the plant, and the 50 KW DC generator, and installed a 50-ton ice plant in the boiler room. The ice plant was not a profitable venture. After the property was acquired by the American Utilities, it was sold in 1931 to Devere Joslin. He moved the entire ice plant to the ice plant he was operating at 6th and Rolla Streets.

The first power plant building in Rolla, built about 1880, was a metal structure (a picture of this building is at the Rolla Municipal Utilities office). It was replaced by a brick structure about 1910. The new brick building at the same location was used not only for a power plant, but the north side of the building was partitioned off as a Council Chamber and Mayor's office, with the city jail

located in the east end. When Mrs. Holcomb bought the property and installed the diesel engines, the city offices and jail were removed.

In 1930, the Missouri Electric Power Company, now Sho-Me Power Corporation, a subsidiary of the Central States Light and Power Company of Dubuque, Iowa, built a 33,000-volt transmission line from a dam they owned on the Niangua River near Lebanon, Missouri, through Rolla to Sullivan and Cuba, Missouri, towns where they owned power systems. The Missouri General Utilities Company contracted to buy power from this line and the diesel engines were shut down and used only for emergency until 1950 when they were junked and removed. In the 1950s The Missouri General Utilities Company converted the electric system from 2400 volts Delta to 4160 volts Wye. It is still operated at this voltage.

In 1949, Rolla severed the Power Contract with Missouri Electric Power Company and contracted with Union Electric Company to serve Rolla. Union Electric brought two 33,000-volt transmission lines into Rolla from a substation about 3 miles north of Rolla known as Phelps Substation. This has been Rolla's source of power since that date.

In 1924, I came from the Dayton Power and Light Company in Dayton, Ohio, to Missouri to manage the properties that American Utilities had acquired in Missouri, Arkansas, and Kentucky. I spent a great deal of time in Rolla because both the electric system and water system needed immediate attention, but I lived for a short time in Kentucky and Arkansas. The situations there were not so acute because the power was purchased from other utilities and there were only two small water systems. The American Utilities incorporated all the Missouri properties as the Missouri General Utilities Company. The American Utilities Company was not well financed, and because of this, was caught in the depression in 1929 and 1930 and was unable to keep the properties they had purchased. To avoid bankruptcy,

they traded all the stock of the Missouri General Utilities Company to the Associated Gas and Electric Company of New York for Associated stock. It was a standing joke at that time that they traded nothing for nothing, as Associated was also on the verge of bankruptcy. I remained with Associated until they were forced by the 1938 Federal Holding Company Act to sell the properties they owned, which were not integrated, and this included all the Missouri properties. In 1945 they sold the Rolla properties and the City of Rolla purchased them for \$450,000. So after 27 years, the city again owned the electric and water systems in Rolla. The city had voted a bond issue to cover the purchase price and took over operation on November 1, 1945, under a Board of Public Works and called it the Rolla Municipal Utilities. The trustees of Associated offered to move me to Erie, Pennsylvania, and place me in charge of a group of towns they owned, but I elected to stay in Rolla. I operated the electric and water system for the city of Rolla from 1945 until 1970 when I retired and was succeeded by Mr. William E. O'Haver. Mr. O'Haver came to work for the Rolla Municipal Utilities as a laborer in 1952 at the age of 25.

In the early 1900s the only water available in Rolla for human consumption came from shallow wells and cisterns. Nearly every home had one or the other. There were several public wells used by the citizenry and during dry spells water was carried from these wells, which had the old type cylinder pump and the famous old pump handles. I never saw these wells, but when I first came to Rolla in 1924 the old timers told me about them. One was located at the end of Sixth and Pine Street and supplied a large watering trough. Another was somewhere in the front yard of the Courthouse at Third and Main. As late as 1930 the old stone base over this well was visible, but since then has been removed. Others were near the Frisco Depot, on Salem Avenue near East Fifth Street, and at the rear of the old Grant Hotel at Eighth and Pine. There were several large cisterns that had roof drains into them from nearby buildings, which were used for fire fighting. One of these was located at Eighth and Pine and was intact until recent years. The 8-inch water main at Eighth and Pine runs through the top of this cistern. Since 1924 several of these old cisterns have been discovered, but I believe all of them have been filled in.

Rolla's first fire fighting equipment was a bucket brigade. Later, a hand-operated fire pump and a hose cart were purchased. This cart is on display at the fire department building at Fourth and Main Street. Today, Rolla has a well-organized, well-equipped fire department.

About 1904, the population of Rolla was about 1,800 and the town started a campaign to drill a large well and install a system of mains and a storage tank. In 1905, 1906, and 1907 this system was installed. The mains were

8-inch, 6-inch and 4-inch, with valves, fire hydrants, and a concrete storage tank on the north side of the town at Tower Road. In 1915, this tank, which was never satisfactory because of leakage, was abandoned and replaced with a 240,000 gallon steel standpipe 30 feet in height, erected by the Chicago Bridge and Iron Company. The tank was replaced in 1954 by an 800,000 gallon steel standpipe, 30 feet higher to increase the water pressure by 12 pounds. It was also erected by the Chicago Bridge and Iron Company. The 240,000 gallon standpipe is now used for storage of electric and water supplies. The 800,000 gallon standpipe is still in use (1975). Many of the original Corey fire hydrants installed in 1905, 1906, and 1907 are still in use and all the original cast iron, lead joint mains are also in use. The Missouri School of Mines drilled a well in 1906 and 1907 and a 4-inch cross connection was made from the city system at Twelfth and Pine into the Missouri School of Mines system for the mutual benefit of the City of Rolla and the Missouri School of Mines. This connection was eliminated in 1968 when other larger connecting mains were installed.

In about 1906, the town let a contract for an 8-inch well to a Mr. H. W. Steinsick to be drilled on the south side of Eighth Street, east of the power plant building, east of the Frisco Railroad. He encountered many troubles drilling the well. He started two or three wells, but because of crooked holes and the loss of drilling tools, they were abandoned. Through the years, this has been verified by uncovering the old steel casings on the east side of the power plant. Finally, in 1907, he completed a well to 800 feet and the log shows that it pumped 200 gallons per minute. The well was pumped with air using a system devised by Professor Harris at the Missouri School of Mines. This was accomplished by running a 1½ inch steel pipe air-line into the well below the water-level (water level not known), and pumping air at 150 lbs. of pressure down this pipe. The water was forced up the casing and ran from the top of the casing into a 40,300 gallon underground concrete reservoir adjacent to the well. From this reservoir the water was pumped by a centrifugal pump, located inside the power plant, into the water system. The air compressor used for the first well was evidently operated by steam pressure. In 1924 there was an old steam engine still in the power plant, but it was replaced with deisel oil engines in 1918, 1922, and 1923. The production from this first well was given as 200 gpm when it was drilled, but in 1924 the well was only producing about 100 gpm. At times the water was cloudy and sandy, but by letting the water settle in the underground reservoir, the sand settled out and the water could be used. It was not good quality water. There were many complaints and considerable bleeding of the fire hydrants to get out part of the sediment. This well was plugged about 1935 and the underground reservoir was filled in about 1942. The old residents told many tales about the troubles the city had with this first water

system. The installation of the mains were completed about 6 to 8 months before the well and there was no way to test the mains for leaks. When water was finally pumped into the mains there were leaks everywhere. The city brought suit against the contractor who installed the mains (contractor not known), but he returned and dug up and repaired the mains and the suit was dropped. The mains did not make water available to all the houses by being installed on every street. The city permitted houses on side and back streets to lay their own service lines to the mains. There were many such lines installed and practically all of them were $\frac{1}{2}$ and $\frac{3}{4}$ inch iron pipe laid across private property through front and back yards or alleys, and even from one basement to the next. There were no records of valves on the water system, other than a designation on the plat map that a valve was located at or near a street intersection. Neither were there any maps of service lines to many homes. When a service line was found on a main with no indication where it went or who it served, it was common practice to open the goose-neck and pour in a small amount of peppermint oil. This soon brought a response from the customers that this line served. In many cases it served three or four houses, some with water meters and others not. It was not until the late 1940's that these conditions were eliminated and corrected by the installation of new mains, and the use of copper service, and the completion of a map of the water system.

A great many conferences were held in 1925, 1926 and 1927 between the American Utility officials, the citizens of Rolla, and the Missouri Geological Survey on what steps should be taken to furnish an adequate water supply. The American Utility officials investigated the possibility of building a large water plant on the Piney River at Newburg and pumping the water into Rolla, but they soon recognized that the cost of this was far more than they could finance. Finally, in 1928, it was decided that a new well should be drilled at a suitable location and a new turbine type electric driven pump installed. A lot was purchased on the north side of Seventh and Walnut streets. The specifications for the well were prepared by the Missouri Geological Survey, who asked that the well be drilled 12 inches in diameter down to 500 feet, and 8 inches in diameter through the Potosi, terminating at the base of the Lamotte at approximately 1,750 feet, or when the drilling samples showed the Lamotte had been penetrated. It was the general opinion of many geologists at that time that a big flow of water was available only from the Lamotte.

This Well #1 (known by Missouri Geological Survey Records as Well #2) was completed at 1,765 feet in 1930 and 1931. There was only about 100 feet of 12-inch steel casing installed. This casing was set down in concrete, and concrete filled in around the casing from the top.

The well was drilled by the Alexander Company of Springfield, Missouri, at a contract price of approximately \$8,500.00, but they were unable to complete the well because of financial problems; it was completed by the bonding company (driller not known). The first pump was a Byron-Jackson installed by Reeves and Skinner Pump Company of St. Louis. Evidently the pump was too light and fragile for the 400-foot setting in the well, and never operated satisfactorily. In removing the pump from the well in 1931, the column broke and part of the pump fell to the 500 foot level, and lodged in the 8-inch hole. After some three months the pump was fished out in pieces, but the well had caved in badly, and had to be drilled and bailed out from 800 to 1,200 feet, and a liner installed. In 1931 a Pomona, and later a Layne-Western pump was installed, which operated until about 1965 when the well was abandoned due to low production. Originally, the well produced about 350 gpm. It was a dependable supply for about 30 years. This well was plugged in 1966.

By 1930 there were signs that Rolla was destined to increase in population, due to the growth of Missouri School of Mines and the United States Geological Survey. In 1931 and 1932 Well #2 was drilled at Fourth and Rolla Streets. The same specifications were used as for Well #1, except 375 feet of 12-inch casing was installed. This well was completed to approximately 1,715 feet, and produced about 440 gpm of fine quality water. This well is still in production, but now has a capacity of only 270 gpm.

In 1942 there was a great influx of people into Rolla, due to the establishment of Fort Leonard Wood 35 miles south of Rolla. The federal government recognized that the towns near Fort Wood needed some financial assistance, and made funds available for improvements to the water and sewer systems in several towns. Rolla received a grant for a water well and additions to the sewer system. Well #3 was drilled in the northeast corner of Rolla at Arkansas and Holloway streets. It was a 10-inch hole down 500 feet and 8-inches down through the Potosi to 1,200 feet. This well produced 440 gpm. The well discharged into a 240,000 gallon concrete reservoir and was pumped from the reservoir by a centrifugal pump into the water system. This tank was abandoned in 1955 and converted to a storage facility for electric and water supplies. The deep well pump was rebuilt and connected directly into the water system.

In 1947, Well #4 was drilled on East Tenth Street and Well #5 at Walker Avenue and the Frisco Railroad. These wells were 12 inches in diameter down to 500 feet, and a 10-inch hole through the Potosi to approximately 1,200 feet. Each produced approximately 540 gpm. These wells were not drilled through the Lamotte at

1,700 feet because a well drilled by Missouri School of Mines in 1936 found that the water in this locality was coming from the Potosi instead of the Lamotte (see account of Missouri School of Mines Well #2 drilled in 1936 later in this report). Because of this, all wells drilled after 1936 were approximately 1,200 feet in depth.

In 1952, Well #6 was drilled on West Tenth Street, just west of Phelps County Memorial Hospital. This well was drilled by the same specifications as Wells #4 and #5, and produced approximately 545 gpm.

In 1954, Well #7 was drilled on Williams Road approximately 1,200 feet west of South Rolla Street. This well was drilled by the same specifications as #4, #5, and #6, and produced 525 gpm. There were signs of contamination from the first samples pumped from the well, but after the well operated for 15 or 20 minutes at 525 gpm the water tested okay. This continued for over a year. A 100,000 gallon storage tank was installed at the well and the well was discharged into this tank, treated with chlorine and then pumped into the system with a centrifugal service pump. This eliminated all contamination.

In 1960, Well #8 was drilled at the site of the old sewer plant south of Highway 72 at Sharon Avenue. This well was drilled to the same specifications as all the previous wells, but never produced a supply of water comparable with the previous wells. The maximum production was approximately 260 gpm. The well has been deepened and acidized several times and the pump setting lowered, but production has not improved.

In 1966, Well #9 was drilled on Bridge School Road, approximately 600 feet east of I-44 on land owned by the United States Forest Service, to the same specifications as all the previous wells. This well produced 750 gpm of good water.

In 1965, the city installed a 1,800,000 gallon steel standpipe on Lanning Lane on the south side of the city to maintain better pressure on the city's south and west side. This makes a total of 2,700,000 gallon storage capacity above ground (1,800,000 on Lanning Lane) (800,000 on Tower Road) & (100,000 at Well #8 on Williams Road).

In 1967, Well #10 was drilled on the north side of I-44 east of Vichy Road to the same specifications as all previous wells. This well produced 775 gpm of good water.

In 1972, Well #11 was drilled in Heritage Heights, a new subdivision at Liberty Drive and Lincoln Lane. This well was drilled by air rotary with detergent additives to the same specifications as all the other wells. This well produces approximately 1,000 gpm.

In 1936, the Missouri School of Mines (now University of Missouri at Rolla), due to their growth and the falling production of their original Well #1 drilled in 1907, decided to drill their Well #2 on the north side of the campus at Vichy Road and 16th Street about 25 feet south of their steel storage tank. The specifications for this well were reviewed and approved by the Missouri Geological Survey, and were the same as for the city's Wells #1 and #2. The Virginia Drilling Company of the State of Virginia was the low bidder and drilled the well. They lost their first hole at 200 feet, but moved over a few feet and drilled a second hole. It was never fully understood why the Virginia Drilling Company bid a well job some 1,000 miles from their home base. Hancock, who drilled the well, was an experienced and capable driller. When the well was down to 1,200 feet through the Potosi, the driller insisted that he had a big supply of water. He was so insistent that it was decided to install the pump and run a test on the well. This was done and the test showed that the well would produce 340 gpm. State Geologist Buehler and his Associate, H.S. McQueen, decided to stop the drilling at the base of the Potosi at the 1,200 feet level, and operate at that level.

As a result of the water production at the base of the Potosi, as this well indicated, all wells after 1936 have been drilled through the Potosi. This well was abandoned and plugged in the early 1970s.

In 1940 and 1941, the Uptown Theater asked the Missouri General Utilities Company, owner of the Rolla Water System, for permission to take water from the city water system and circulate the water through a system of coils in the Uptown Theater to cool the building. There was no way, without laying considerable main, to take water and return it, except to the same main. The State Board of Health would not approve of such a connection and the idea was abandoned. Against the advice of several engineers, the Uptown Theater decided to drill their own well on the east side of the Theater Building at 11th and Pine Streets for a supply of water. They drilled a 700 foot well in 1942, which produced approximately 80 gpm. They soon found that 80 gpm of 55 degree water would not cool the theater, so they abandoned the well and later put in air conditioning.

In the early 1950s, John Schuman had built and was operating the Busy Bee Laundry at 14th and Elm Streets. He had tried to use water from the Frisco Pond for his laundry, but he did not have the proper filtering equipment, and was not willing to finance the installation of this equipment. He thought the city water rates were excessive, so he drilled a well in 1953 at the west side of the laundry building. The well was 675 feet deep and a turbine type pump was installed. The well produced from 50 to 60 gpm and is still in operation. At the present time, it is producing approximately 5½ million gallons annu-

ally, but there have been a number of times when the pump has broken down and no water used from the well for a considerable time. This well was drilled by Roy Wallace. It is not properly cased and should be plugged as it is deeper than the point where the city wells are cased and could become a source of contamination.

In 1964, the University of Missouri at Rolla drilled their Well #3 on the west side of Rolla. The well was drilled by Clark and Son of Pacific, Missouri, to a total depth of 1,205 feet, with 390 feet of 12-inch casing, and producing 570 gpm. In 1967, the University of Missouri at Rolla and the Rolla Municipal Utilities entered into an agreement for the utility company to take over the operation of this well, and supply all the water used at the University of Missouri at Rolla.

In 1968, Zeno's Motel drilled a 545-foot well at their motel on Highway 66 Wes. It was drilled by Roy Wallace. This well is still being used and produces approximately 3 1/2 million gallons per year.

In 1962, Holiday Inn drilled a 650-foot well at their motel on Highway 66 Wes. It was drilled by Roy Wallace. The city installed an 8-inch main along Highway 66 West in 1964 and this well was abandoned. It is now used as an observation well by DGLS.

There are shallow wells at Plaza Trailer Park, and also Woodcrest Trailer Park on the west side of Rolla. Plaza Trailer Park well produces approximately 2 million gallons per year. Woodcrest Park well produces approximately 6 3/4 million gallons per year.

All the wells in Rolla always had iron content of .20 to .30 ppm. This caused a red rust deposit in the mains, and there were always complaints from customers on dead end mains, and mains with low flow, of red water and an odor. This necessitated a regular program of fire hydrant bleeding, and even this did not correct the trouble. As more water was pumped from the well the situation seemed to worsen.

In 1953 and 1954, Dr. W.T. Schrenk, Chairman of the Chemistry Department at Missouri School of Mines at Rolla, thought that cutting off mains from the system and circulating a lime solution through these mains would help the problem. It did some good, but we were told by others who had the same problem that the only solution was the use of chlorine injected into the system at the pump head.

In 1956, we retained Haskins, Riddle, Ordelheide, and Sharp Consulting Engineers to install some temporary chlorinators to see what results might be achieved. We learned that the chlorine cut the rust loose in the mains

and over a length of time would partially control the rust and odor problem. We installed permanent chlorinators, but after some 19 years the rust condition is still a serious problem; however the taste and odor has improved. Approximately 1 ppm of chlorine is added to the system.

The citizens asked for fluoridation of the city water system. The Board of Public Works said that it would be done if there was a referendum approving it. It was voted in and the fluoridation equipment was installed in 1968.

When the city purchased the utilities in 1945 from the Trustees of the Associated Gas and Electric Company, they set up a Board of Public Works, as provided by state law, to operate the electric and water system. The original Board members were F.H. Frame, H.E. Castleman, Eric Schuman, and Fred Cameron. These men are now deceased, but have always been credited with giving Rolla a sound utility background for the operation of the utilities.

In the early 1960s, the Missouri Inspection Bureau gave Rolla a Class VII Fire Insurance rating for all property inside the corporate limits. This was occasioned by the continued improvements to the water system, improvements in the fire department equipment and personnel, enactment of an improved building code, and inspection services covering construction.

All the wells that have been drilled in Rolla for the city, except the first well at the power plant and Well #1 on Seventh Street, were drilled and equipped by the Layne Western Company. All well locations and specifications were also approved by the Missouri Geological Survey (later by DNR) and the State Board of Health.

All wells in Rolla, except Well #11, have been drilled with cable tools. This consists of using a long steel drill stem approximately 5 inches in diameter, with a sharp edged bit on the end, and lifting and dropping this stem and bit by a steel cable to cut its way through rock and dirt to the well depth. Well #11 was drilled by the air rotary method with detergent additives to wash the drillings out of the hole. A hollow drilling stem with a sharp edged bit on the end is rotated, and the detergent pumped down the inside of this drill stem and up and out on the outside of the stem. Many advantages are claimed for this method, but because of their technical nature and length, are not included in this history.

Water samples from all the wells, and the distribution system, are continually checked by the Missouri Division of Health, and the analyses have shown Rolla water to be pure and of high quality. Periodically, they also do a chemical analysis of the water.

The city wells are numbered 1, 2, 3, etc., but the first well at the power plant was omitted. The Missouri Geological Survey called the old power plant well #1, so the well designated #1 by the city is #2 by the Missouri Geological Survey records and #2 city is #3 Missouri Geological Survey, #3 city is #4 Missouri Geological Survey, etc. (NOTE: this discrepancy has been corrected and RMU/DGLS now use the same well numbers).

In 1945, the Board of Public Works purchased the building at 102 West Ninth Street, which the government built during World War II to house the U.S.O. With a few changes, the first floor was made into offices for the Rolla Municipal Utilities. The Rolla Public Library occupied the second or top floor, which had been used for U.S.O. shows and dances.

The Phelps County Agent and State Board of Health occupied the basement. In May 1965, the library moved to the old Post Office building at Ninth and Pine, and the Board of Health moved to the Courthouse. Today, the Rolla Municipal Utilities use all the building but the

basement for their operations. The basement is still used by the County Agent, better known as the Extension Division of the University of Missouri.

The revenue from the water system in Rolla is not now (1975), and has never been, sufficient to cover the cost of operation. The electric and water systems have always been operated by the same management and personnel, and subsidized by the electric operation. For this reason the water rates in Rolla have always been low. The feeling seemed to exist to "let the electric department carry the load" and this policy was in vogue for many years.

From the beginning when the first water well drilled in the 1930s, there has been a general feeling or opinion in Rolla that when we need more water we will just drill another well, but about 10 years ago, with the growth in population and increased water consumption, RMU realized that a careful survey should be made to determine where future wells should be drilled, and perhaps a systematic plan of well operation from day to day.

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April 1993

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